US Army Corps of Engineers

AD-A190 607

STRUCTURES LABORATORY

(2)

TECHNICAL REPORT SL-87-31

DYNAMIC TEST OF A CORRUGATED STEEL KEYWORKER BLAST SHELTER MISTY PICTURE

by

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November 1987

Final Report

Approved For Public Release. Distribution Unlimited

Prepared for Federal Emergency Management Agency
Washington, DC 20472

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report SL-87-31	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES Structures Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Federal Emergency Management Agency 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) 500 C Street, SW, Room 716 Washington, DC 20472	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Dynamic Test of a Corrugated Steel Keyworker Blast Shelter: Misty Picture

12. PERSONAL AUTHOR(S)
Holmes, Randy L., Slawson, Thomas R., Harris, Aaron L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ______ TO ______	November 1987	93

16. SUPPLEMENTARY NOTATION
Available from National Information Service, 5285 Port Royal Road, Springfield, VA 22161

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	Blast effects	Shallow-buried structures
			~~Explosions~~	Soil-structure interaction
			Nuclear Blast Shelter	Structural design

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The 18-man blast shelter was tested dynamically on May 14, 1987 in the MISTY PICTURE event at White Sands Missile Range, NM. The main section of the shelter was fabricated from a 9-foot-diameter, 27.5-foot-long section of 10-gage, galvanized, corrugated steel culvert. The shelter included a vertical entryway and air intake and exhaust stacks.

The shelter design was found to be conservative during a previous 50-psi validation test, and some constructibility problems were encountered with the entryway-to-shelter connections. This test was conducted to validate the modifications made to the shelter design. The modifications were made to reduce construction costs and improve constructibility. Primary modifications included: replacing the stiffened endwalls with lighter weight unstiffened plates, connecting the entryway to an endwall rather than to the main section of the shelter, and the inclusion of an emergency exit. The structure was located at the anticipated 200-psi peak overpressure level.

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. ABSTRACT (Continued).

Posttest inspection revealed that the main section of the shelter suffered very little damage during the test. The midlength vertical diameter increased approximately 1.4 inches and the horizontal diameter decreased approximately 1.4 inches. Rigid-body vertical displacement was 3.7 inches downward. Endwall deflections were less than 0.7 inch, and the emergency exit failed during the test.

Due to the failure of the emergency exit cover plate, it was necessary to determine if enough pressure entered the shelter to affect its structural response. Since the magnitude of the internal pressure was relatively small in comparison with the overpressure measured at the ground surface, the pressure inside the shelter did not significantly affect the structural response of the shelter.

This test also investigated the shock environment inside the shelter. Comparisons of shock spectra with typical equipment fragility curves were made.

Based on test results, it is concluded that the shelter has the reserve capacity to resist overpressures as high as 148 psi from a 8-kt nuclear detonation without catastrophic failures, provided a redesign of the emergency exit is performed.

DYNAMIC TESTS; DYNAMIC RESPONSE; Nuclear Explosion testing; Nuclear explosion damage.

PREFACE

The research reported herein was sponsored by the Federal Emergency Management Agency (FEMA) through the US Army Engineer Division, Huntsville (HND), in support of the Keyworker Blast Shelter Test Program. Mr. Jim Jacobs, FEMA, was the Program Monitor.

The test was conducted by personnel of the Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES), under the general supervision of Messrs. Bryant Mather, Chief, SL; J. T. Ballard, Assistant Chief, SL; and Dr. J. P. Balsara, Chief, Structural Mechanics Division (SMD), SL. Dr. S. A. Kiger, SL, was the Project Manager. The test was conducted under the direct supervision of Mr. T. R. Slawson of the Research Group, SMD. The field test was supervised by Mr. R. L. Holmes of the Structural Evaluation Group, SMD, and Mr. Slawson. The structure and the free field were instrumented by Messrs. H. P. Parks and F. D. Shirley of the Instrumentation Services Division (ISD), WES. The data sampling rates were designed by Messrs. R. E. Walker, Chief, Structural Analysis Group, SMD, and R. J. Dinan of the Explosion Phenomena Section, ISD. Messrs. J. K. Ingram, B. J. Armstrong, Jr., and J. Brogan, Explosion Effects Division, SL, performed the data reduction and plotting.

The data recording was done by Messrs. Lawrence Barnes, Senior Field Engineer, and David Garcia, Senior Technician, of the Bendix Corporation.

This report was prepared by Messrs. R. L. Holmes, T. R. Slawson, and A. L. Harris (SMD).

COL Dwayne G. Lee, CE, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
gallons (US liquid)	3.785412	litres
g's (standard free fall)	9.806650	metres per second squared
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	25.4	millimetres
kilotons (nuclear equivalent of TNT)	4.184	terajoules
megatons (nuclear equivalent of TNT)	4.184	petajoules
pounds (force) per square inch	0.006894757	megapascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre

DYNAMIC TEST OF A CORRUGATED STEEL KEYWORKER BLAST SHELTER: MISTY PICTURE

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

At the time this study was initiated, several civil defense policy options were being analyzed for the protection of industrial capability and key workers. One option under consideration called for a program to construct blast shelters that would provide protection for key workers remaining in high-risk areas during a national security crisis.

In support of this policy, the Federal Emergency Management Agency (FEMA) tasked the US Army Engineer Division, Huntsville (HND) to develop Keyworker shelter designs. The US Army Engineer Waterways Experiment Station (WES) assisted HND in the testing and the analysis of the shelter designs. The 18-man blast shelter consisted of a 9-foot-diameter steel culvert section approximately 30-feet-long with endwalls, a vertical entryway, a ventilation system and an emergency exit. The shelter design criteria required that the shelter survive a peak overpressure of 50 psi from a 1-MT* nuclear weapon. This requirement and the levels of initial and residual radiation associated with the threat weapon dictated that an earth-covered shelter with a depth of burial of 4 feet be used.

The original design of the 18-man blast shelter was validated at the design load conditions by Woodson, Slawson and Holmes (1986). The design was found to be conservative, and some constructibility problems were identified with the entryway-to-shelter connection. Based on the test results and consultation with Messrs. Conrad Chester and Greg Zimmerman of the Oak Ridge National Laboratory, design changes were proposed.

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* A table of factors for converting non-SI to SI (metric) units of measurement is presented on page 4.

Primary modifications of the shelter design consisted of replacing the stiffened endwalls with lighter weight unstiffened plates, connecting the entryway to an endwall rather than to the main section of the shelter, and the inclusion of an emergency exit. It was decided to test this design during the Defense Nuclear Agency (DNA) sponsored 8-kt High Explosive event, MISTY PICTURE at the predicted 200-psi peak overpressure level. This report describes the test and presents the results obtained.

1.2 OBJECTIVES

The primary objective of this study was to verify the response of the 18-man blast shelter in an overload (relative to the design loading) environment. This included verification of the following: the integrity of the shelter, the design of the modified endwalls, the design of the entryway-to-shelter connection, and the design of the emergency exit.

1.3 SCOPE

The shelter was provided to WES by HND and was tested dynamically during the high-explosive event, MISTY PICTURE. The shelter was placed at a distance of 490-feet from the high-explosive charge at the predicted 200-psi peak overpressure level. The charge was designed to simulate the airblast and ground shock components of an 8-kt surface burst.

CHAPTER 2

TEST DESCRIPTION

The 18-man blast shelter was tested dynamically on May 14, 1987 in the MISTY PICTURE event at White Sands Missile Range, NM. The explosive charge consisted of approximately 4,685 tons of an Ammonium Nitrate and Fuel Oil (ANFO) mixture contained in an 88-foot-diameter hemispherical fiberglass shell. The shelter was located 490 feet from the high-explosive charge at the predicted 200-psi peak overpressure level. The shelter and test bed construction, material properties, and instrumentation are described in the following sections.

2.1 CONSTRUCTION DETAILS

The blast shelter shown in Figure 2.1 was furnished by HND. It was constructed by a private contractor in accordance with the plans and specifications provided by HND. Detail drawings of the shelter are presented in Appendix A.

The main section of the shelter was fabricated from a 9-foot-diameter, 27.5-foot-long section of 10-gage, galvanized, corrugated steel culvert. The entryway shaft and ventilation stacks were constructed from 14 gage, 36- and 12-inch-diameter culvert sections, respectively. The entry hatch was constructed from a 1/8-inch-thick dished plate that was filled with vermiculite and covered with fiberglass as shown in Appendix A, Detail 1. The endwalls were constructed from ASTM A36, 3/16-inch-thick steel plates. All structural connections, splices, and joint connections were waterproofed. Steel blind flanges were provided for the air intake and exhaust stacks. These flanges were used to prevent the blast pressure from entering the shelter during the test since blast valves were not included.

2.2 TEST BED CONFIGURATION AND SHELTER PLACEMENT

The test bed configuration is shown in Figure 2.2. The test bed was approximately 50-feet-long, 25-feet-wide, and 14-feet-deep. The backfill material used during this test was a locally available material referred to as

blow sand. A 1-foot layer of blow sand was placed in the test bed prior to placement of the main section of the shelter. Based on the backfill densities obtained using blow sand in similar tests conducted on the WSMR, the initial backfill layer was placed in the test bed with a thickness of 6 inches. Using this layer thickness, the average dry and wet densities were 98.9 lb/cu ft. and 103.6 lb/cu ft., respectively, at an average moisture content of 4.5 percent.

To achieve the desired compaction, all remaining backfill layers were placed in the test bed in 4-inch-thick layers. These layers were compacted using three passes of a Ditch Witch, model DP-190, crawler vibrator, and with two passes of a hand compactor. Where necessary, the area along the sides of the shelter was compacted with a Wacker Rammer, model GVR 200, compactor. Backfill densities and moisture contents were not monitored for each layer but were monitored at various depths throughout the test bed using a Troxler model 3400-B series surface moisture-density gage. The average dry density, average wet density, and average moisture content at midheight of the shelter were 100.9 lb/cu ft., 108.0 lb/cu ft. and 6.6 percent, respectively. After approximately 8-ft. of blow sand had been placed in the testbed, backfill properties were again monitored. The average dry density, average wet density, and average moisture content were 101.5 lb/cu ft., 106.2 lb/cu ft. and 4.4 percent, respectively.

After approximately 3 feet of blow sand had been placed into the test bed, the entryway was bolted to the front endwall as shown in Figure 2.3. The air exhaust stack was bolted to the rear endwall after approximate 4 feet of blow sand had been placed into the test bed. The air intake stack was bolted to the entry shaft after approximately 7 feet of blow sand had been placed into the test bed. After approximately 11 feet of backfill material had been placed in the test bed, the emergency exit shaft was installed. It was placed over the shelter such that approximately 2 inches of blow sand separated the bottom of the emergency exit shaft and the top of the shelter. A total of 4 feet of backfill material was placed over the top of the shelter. The surface of the test bed was leveled and the airblast gage mounts were installed flush with the ground surface at the locations shown in Figure 2.4.

2.3 BACKFILL MATERIAL PROPERTIES

The backfill material used during the test was a locally available material referred to as "blow sand". The blow sand was processed from on-site soil material and classified as a poorly graded silty sand (SP-SM) by the Unified Soil Classification System. Phillips (1986) describes the blow sand backfill used in HE events conducted at WSMR at essentially the same location as the MISTY PICTURE event.

2.4 INSTRUMENTATION

A total of 18 data channels were used during this test. Locations of the gages are presented in Figure 2.4. The data collected during the test were digitally recorded at various sampling rates on a Pacific Model 9833-064-I recorder. The recording of the test data started approximately 45 msec after detonation of the charge, and the total duration of data recording was 1.12 sec. The total memory used for recording each data channel was 64 Kbytes which was divided into 16, 4 Kbyte segments. The sampling rate during each memory segment was varied as shown in Table 2.1 to recover the initial high frequency response and still provide a recording duration long enough to recover the relatively late-time response. The recorded data are presented in Appendix B, and an instrumentation summary is presented in Table 2.2.

2.4.1 Accelerometers

Fifteen Endevco accelerometers, Model 2262C, were used to monitor the structural and free-field accelerations. Thirteen accelerometers (A) were installed to measure structural accelerations at locations shown in Figure 2.4. Two accelerometers were located in the free field to measure vertical (AFF-1V) and horizontal (AFF-1H) accelerations as shown in Figure 2.4.

2.4.2 Airblast-Pressure Gages

Three Kulite Model XT-190 airblast-pressure (AB) gages with ranges of 500 psi were used to monitor the airblast overpressure at the ground surface above the shelter. These gages were positioned at three locations along center line of the shelter at the ground surface as shown in Figure 2.4.

Table 2.1. Data sampling rate summary for each memory segment.

Memory Segment Number	Sample Rate KHz	Segment Duration msec
0	125	32
1	125	32
2	125	32
3	125	32
4	125	32
5	62.5	64
6	62.5	64
7	62.5	64
8	62.5	64
9	62.5	64
10	31.25	128
11	31.25	128
12	31.25	128
13	31.25	128
14	31.25	128
15	Calibration Segment	

Notes:

1. The recording of the test data started 45.048 msec after detonation of the charge.

2. The data recording duration was 1.120 sec.

3. The total memory used for recording each data channel was 64 Kbytes (divided into 16, 4-Kbyte segments). The sampling rate during each memory segment was varied as shown to recover the initial high frequency response and still provide a recording duration long enough to recover the relatively late time response.

Table 2.2. Instrumentation summary.

Gage	Location	Range	Manufacturer	Model
Acceleration (Structure)	A-1	1000 g's	Endevco	2262C
	A-2	1000 g's		
	A-3	1000 g's		
	A-4	200 g's		
	A-5	200 g's		
	A-6	200 g's		
	A-7	1000 g's		
	A-8	1000 g's		
	A-9	1000 g's		
	A-10	1000 g's		
	A-11	1000 g's		
	A-12	1000 g's		
	A-13	1000 g's		
Acceleration (free-field)	AFF-1H	200 g's	Endevco	2262C
	AFF-1V	200 g's		
Airblast pressure	AB-1	500 psi	Kulite	XT-190
	AB-2	500 psi		
	AB-3	500 psi		

Note: Gage AFF-1V and AB-1 were not functional during the test due to lightning damage.

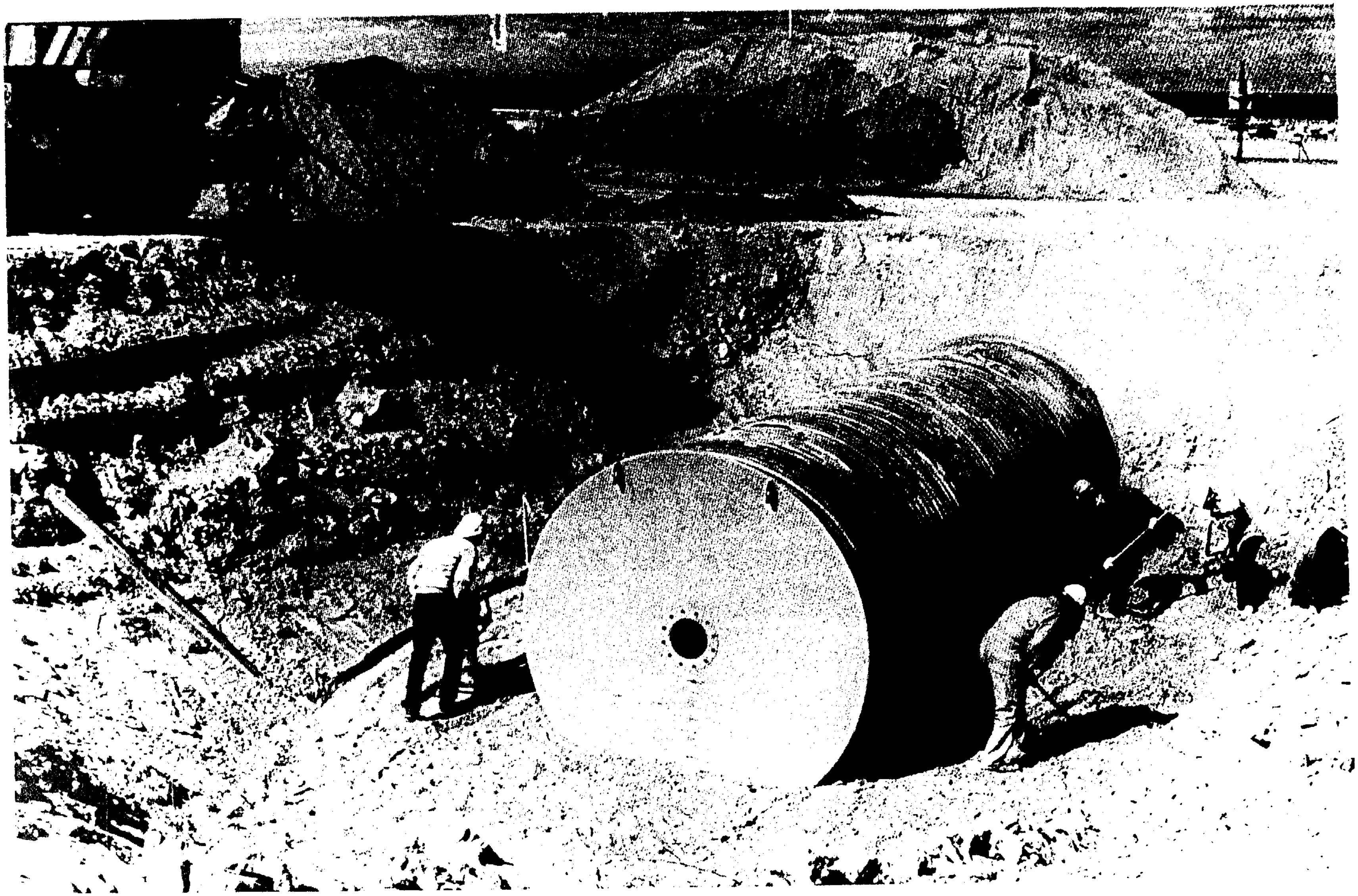


Figure 2.1. The 18-man shelter without the entryway and ventilation system attached.

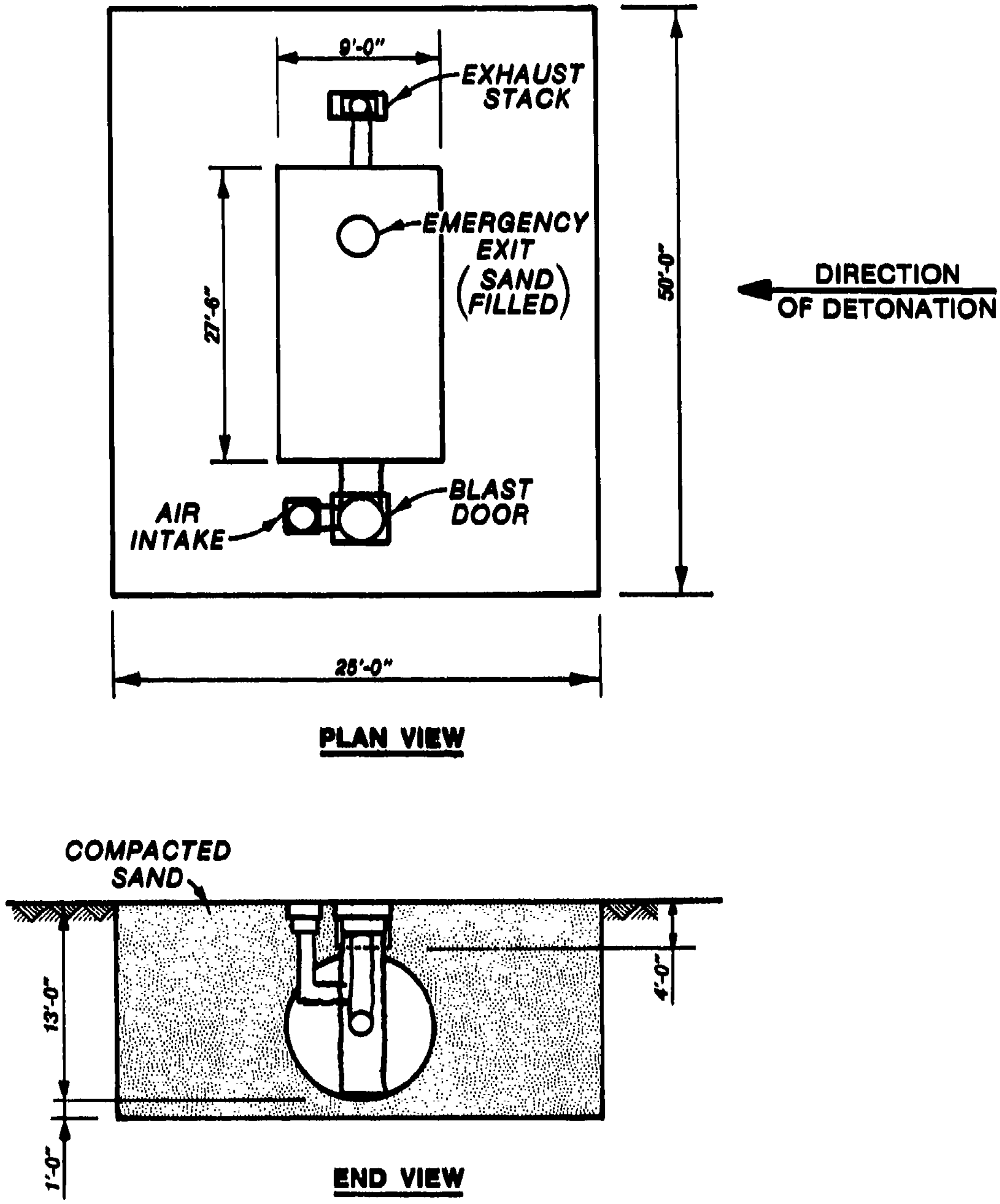


Figure 2.2. Test bed configuration.

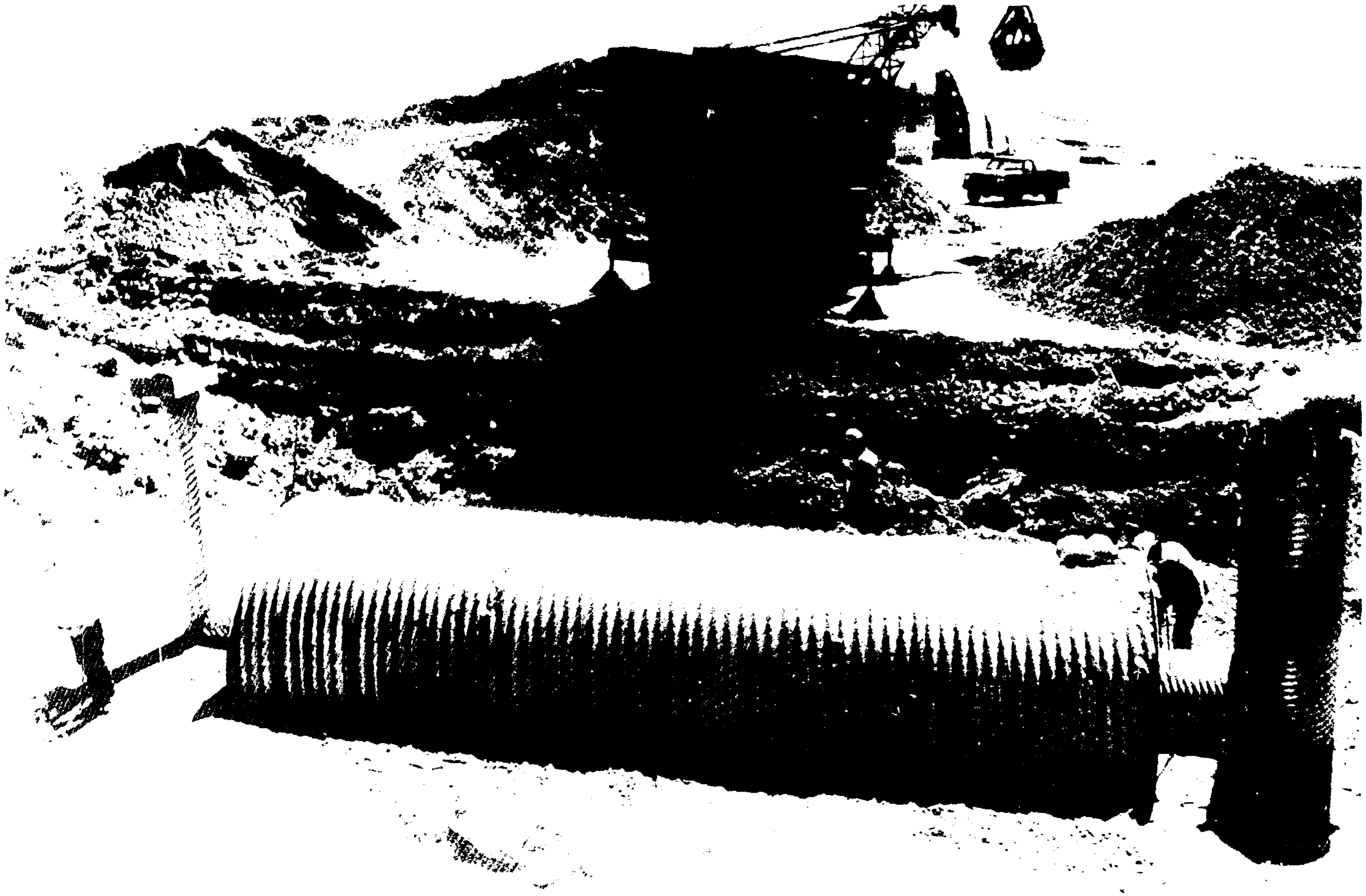


Figure 2.3. The 18-man shelter with the cntryway and air exhaust stack attached.

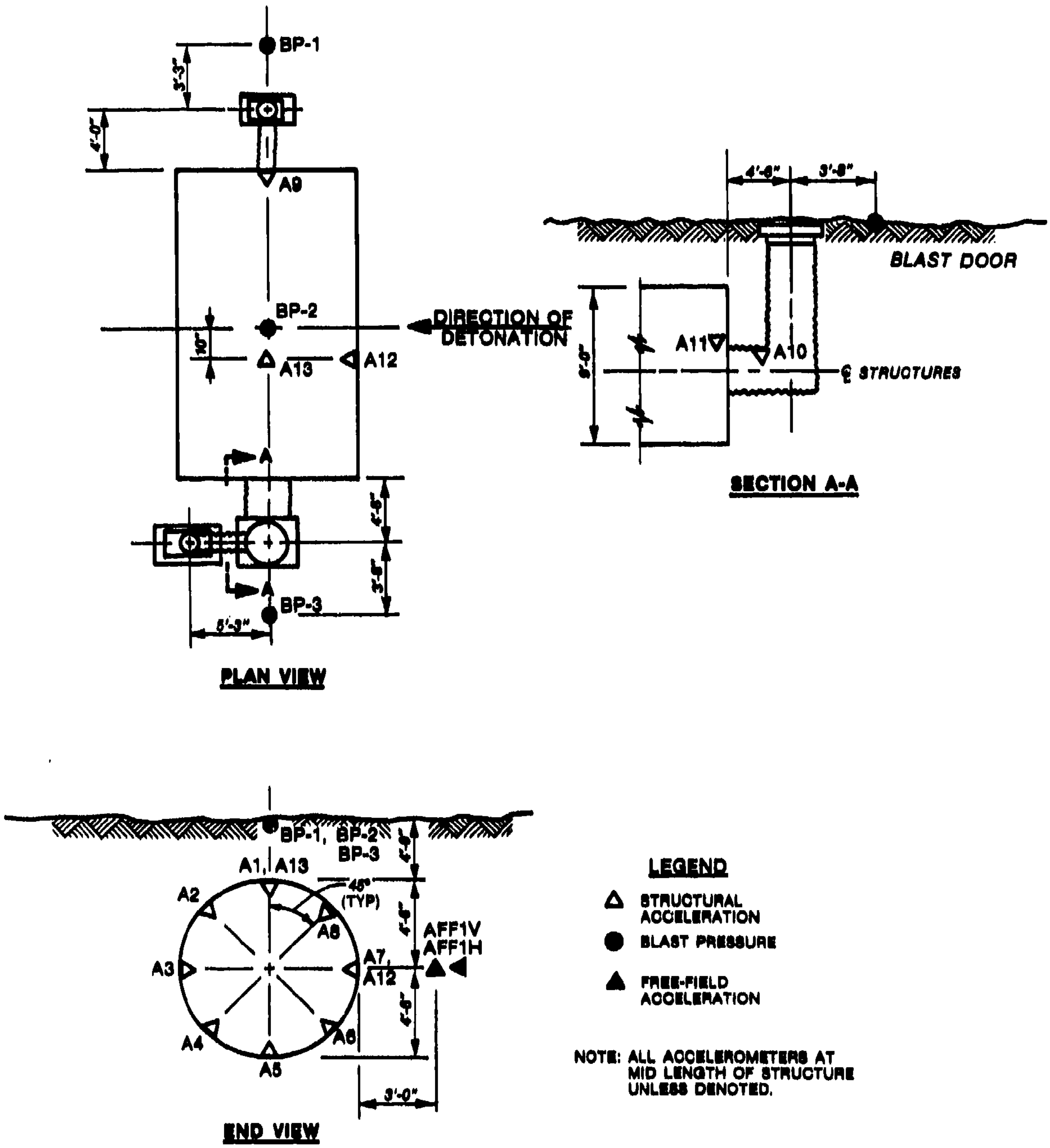


Figure 2.4. Instrumentation locations.

CHAPTER 3

TEST RESULTS

3.1 DAMAGE

Figure 3.1 shows a posttest over view of the 18-Man Shelter. The damage sustained by the entryway hatch and the air intake stack is shown in Figure 3.2. The fiberglass cover on the entryway hatch had a maximum deflection at the center of 3.2 inches. Although the entryway frame was deformed at various locations and the top of the hatch was damaged, the entryway hatch was operational. The damage sustained by the intake stack (Figure 3.2) and the exhaust stack (Figure 3.3) was minor. Posttest inspection revealed that the ventilation system remained structurally sound.

The data presented in Figure 3.4 revealed that the predominant structural response and rigid-body motion occurred during the first 75 msec after the blast wave arrived at the shelter. Overall, the permanent structural deformations were small. The main section of the shelter was slightly ovaled during the test with the midlength vertical diameter increasing approximately 1.4 inches and the horizontal diameter decreasing approximately 1.4 inches. Rigid-body vertical displacement was 3.7 inches downward.

The endwall which supported the exhaust stack had a maximum deformation of 0.6 inch, and the endwall which supported the entryway had a maximum deformation of 0.1 inch.

As shown in Figure 3.5, the emergency exit cover plate failed during the test. The design called for 16, 1/2-inch bolts to connect the emergency exit cover plate to the shelter. These bolts were tack welded to the inside surface of the shelter. The emergency exit cover plate was then bolted in place from the inside of the shelter. Pretest inspection of the shelter revealed that one bolt was missing prior to initiation of the backfilling operation. Three additional bolts failed during the backfilling operation. Observation of these bolts revealed that the bolts failed in shear as the shelter deformed during backfilling. During the test, three bolts pulled through the holes in the emergency exit cover plate and 9 additional bolts

failed in shear. Posttest inspection revealed that only a small area of the emergency exit shaft was in direct contact with the top of the shelter.

3.2 DATA RECOVERY

Sixteen out of a total 18 gages functioned properly during the test. The free-field vertical accelerometer (AFF-1V) and one airblast gage (AB-1) were destroyed during a lightning storm prior to the test. The data collected were of good quality and were consistent. The recovered data records are presented in Appendix B. The data are displayed with time in milliseconds as the abscissa.

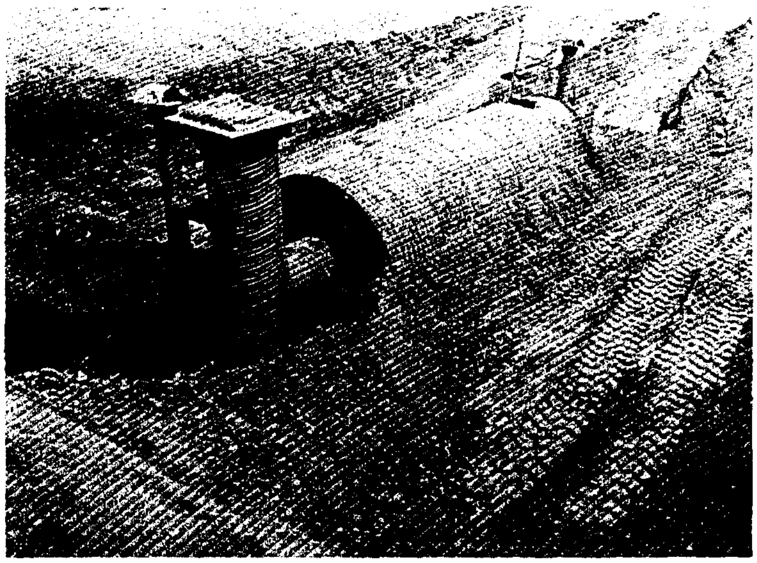
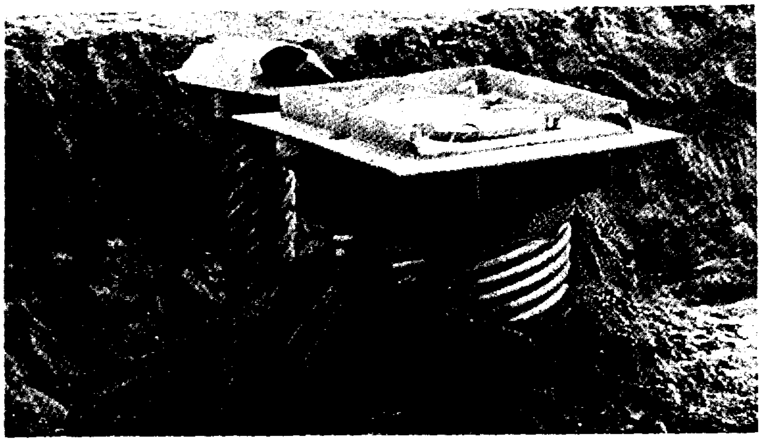
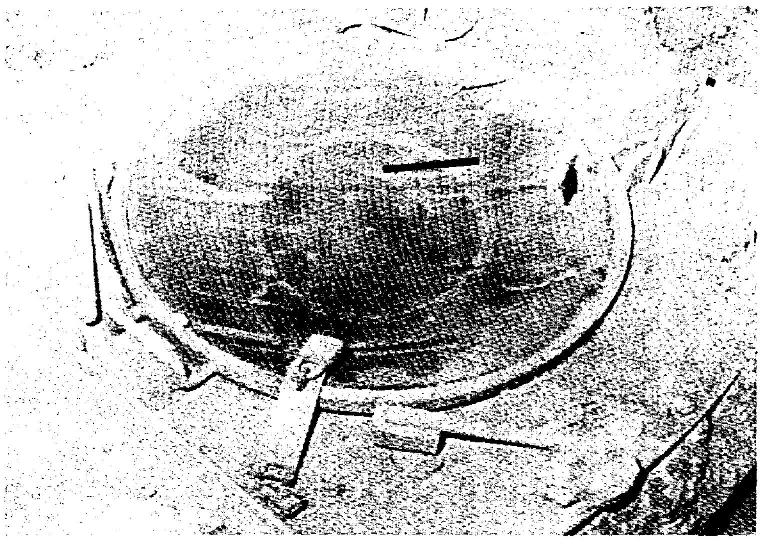


Figure 3.1. Posttest view of the shelter.



a. Entryway hatch and air intake stack.



b. Close-up view of the entryway hatch.

c. Close-up view of the air intake stack.

Figure 3.2. Damage sustained by the entryway and the air intake stack.

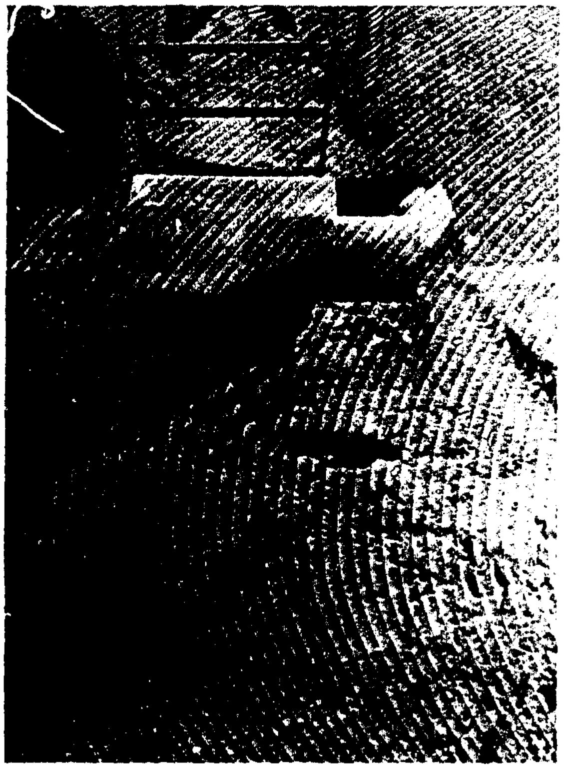


Figure 3.3. Damage sustained by the air exhaust stack.

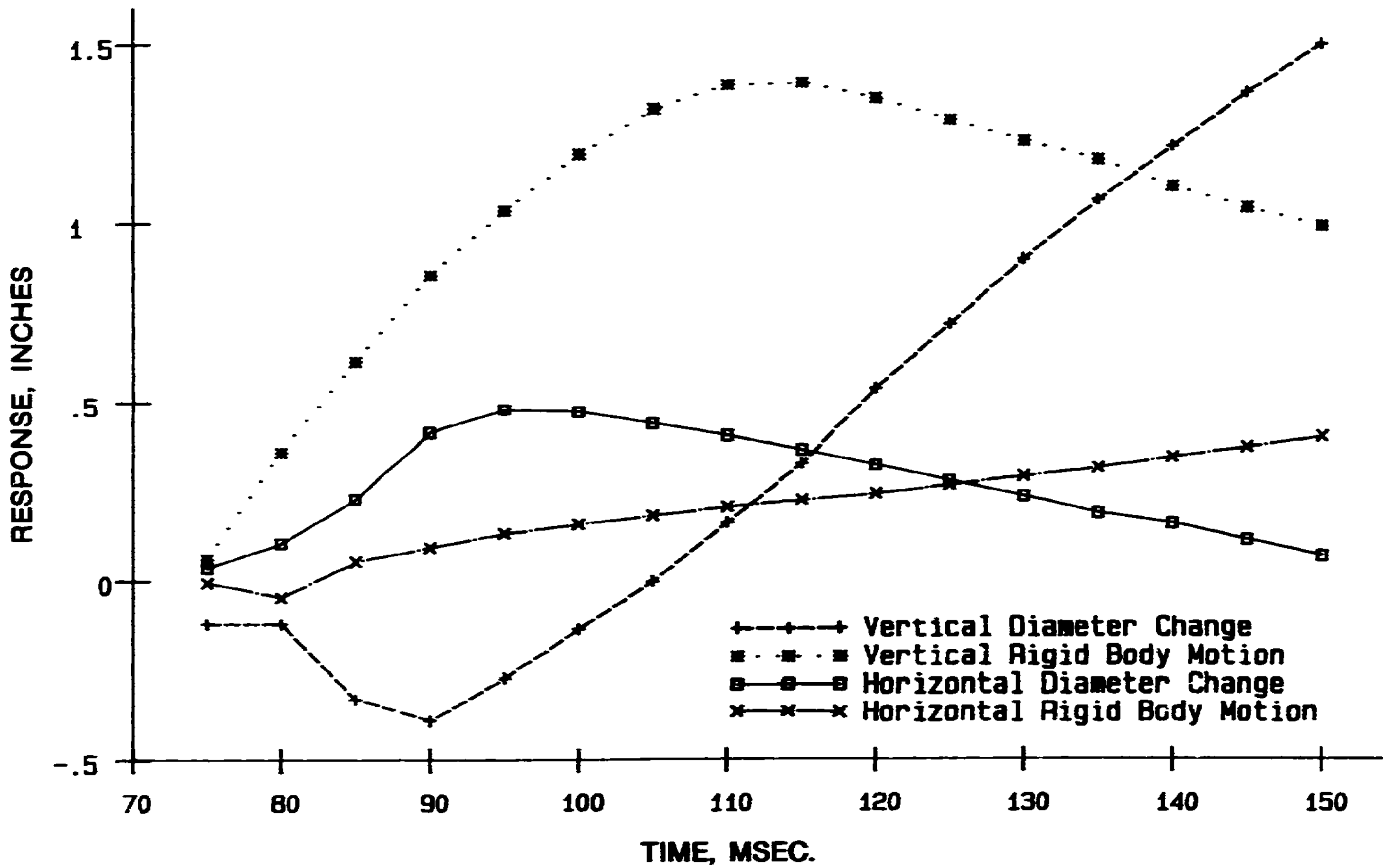


Figure 3.4. Structural diameter changes and rigid-body motion occurring at mid-length of the shelter.

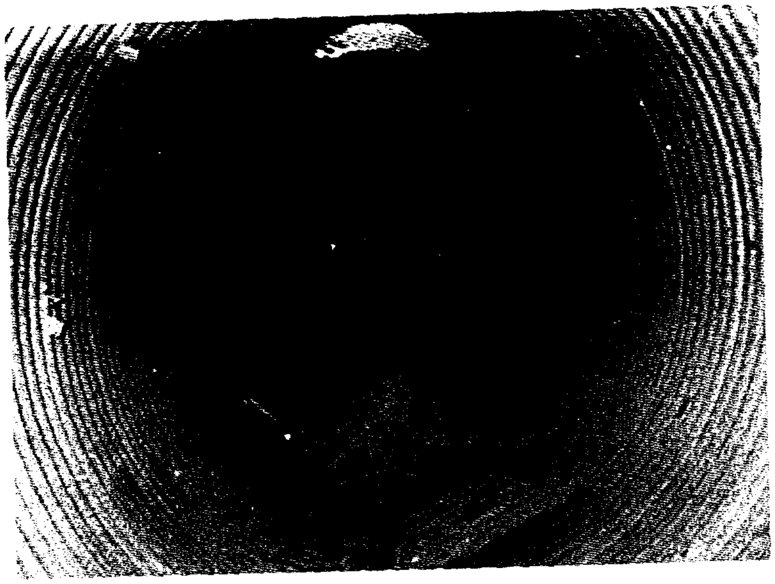


Figure 3.5. Posttest view of the emergency exit failure.

CHAPTER 4

DATA ANALYSIS

4.1 NUCLEAR WEAPON SIMULATIONS

Estimates of the surface-burst nuclear weapon yield and overpressure which best correspond to the airblast data records are required to define the loading function at the ground surface. Weapon simulations were determined by fitting, in a least squared sense, 50 msec of airblast impulse data to nuclear weapon impulse-time curves as defined by Speicher and Brode (1981). The two airblast records were fit individually and collectively using the procedure developed by Mlakar and Walker (1981) and modified by Mr. James Baylot of WES. The average 8-kt weapon fit for the two airblast records was 148 psi and the average best fit was 2.4 kt at 198 psi. A summary of the weapon simulations is presented in Table 4.1, and comparisons of the pressure and impulse data with the simulations are presented in Appendix C.

4.2 IN-STRUCTURE SHOCK

In-structure shock is typically represented in terms of shock spectra. Shock spectra are plots of maximum responses (usually of relative displacement, pseudo-velocity, and/or absolute acceleration) of all possible linear oscillators with a specified amounted of damping to a given input base acceleration-time history.

Shock spectra were generated using acceleration data obtained during the dynamic test as input data for a computer code developed at WES. The shock spectra were constructed using damping values of 0, 5, and 10 percent of critical damping. The shock spectra for A3, A5, A7,and A12 are shown in Figures 4.1 through 4.4.

The shock spectra in Figures 4.2 and 4.5 can be used to determine whether shock isolation is necessary for a given piece of floor-mounted equipment, provided fragility curves for the equipment are available.

Figure 4.5 compares the experimentally determined vertical shock spectra (smoothed by hand and using a damping ratio of 10 percent of critical) for the shelter floor with the fragility curve for typical floor-mounted equipment

(Headquarters, Department of the Army, 1987). Floor-mounted equipment would include items such as generators and communication devices. This comparison indicates that typical floor-mounted equipment would not have survived at the overpressure level of this test. It should be noted that the experimental shock spectra were generated from data recovered from gages located on the shelter and not attached to any floor surface. Typical equipment would be mounted to a plywood floor in an actual shelter. The floor tends to reduce the amplitudes observed in the shock spectra and increases the chances of survival of equipment and occupants.

Based on the results of similar experiments with the equipment installed, performed by Woodson and Slawson (1986); Woodson, Slawson, and Holmes (1986); and Slawson (1987); the fragility curves for typical floor-mounted equipment (Headquarters, Department of the Army, 1987) are design conservative (i.e., the equipment survived at shock levels exceeding their fragility curves). Figure 4.5 indicates that any floor-mounted equipment should be shock isolated to ensure their survivability.

4.3 OCCUPANT SURVIVABILITY

A discussion of human shock tolerance is presented in Crawford and others (1974). The effects of shock on personnel inside the shelter depend on the position of the individual, and the magnitude, duration, frequency, and direction of the motion. Crawford recommends using a maximum design acceleration of 10 g's at frequencies at or below a man's resonant frequency in the standing position (10 Hz). Figure 4.2 shows that the floor acceleration (measured on the inside bottom shelter surface) was less than 10 g's at a frequency of 10 Hz. Also, the use of a plywood floor would decrease the effective shock amplitudes received by the occupants. Since human shock tolerance is higher in the seated and supine positions than in the standing position, the probability of injury decreases for these positions.

Impact injuries occur at much lower accelerations than compressive bone fractures. Generally, impact injuries may occur at acceleration of 0.5 to 1 g for an unrestrained man in the standing or seated positions. These injuries

are the results of falling and hitting the floor or other objects. Impact injuries may be reduced by the use of padded surfaces and/or restraints to prevent movement.

No simulated occupants were employed during this test; however, the results of tests under similar conditions (Slawson, 1987) resulted in relatively small occupant motions that would not have caused compressive fractures and did not result in the occupants falling down or falling off bunks.

4.4 STRUCTURAL RESPONSE

The failure of the emergency exit cover plate allowed blast pressure to fill the shelter. Since internal pressure reduces the effective external structural loading, it was necessary to determine if enough pressure entered the shelter to affect its structural response. Figures 4.6 and 4.7 present the predicted pressure inside the shelter at targets 1 and 2, respectively. Target 1 was located on the floor at midlength of the shelter while target 2 was located at the center of the endwall near the entryway. The Chamber computer program (Britt and Drake, 1986) was used to perform these calculations. The results indicated that a fill-pressure of 7.9 psi at 6.4 msec after the failure of the emergency exit cover plate was present inside the shelter. This predicted internal pressure is considered to be an upper bound since it was assumed that the emergency exit cover plate failed at the instant the airblast pressure wave arrived at the ground surface above the shelter.

Based on the results of the calculations, the shelter filled with pressure at a fast enough rate to have an effect on the shelter's structural response. However, since the magnitude of the fill-pressure was relatively low in comparison with the overpressures measured at the ground surface, the pressure inside the shelter did not significantly affect the structural response of the shelter. From a structural response point of view, it is concluded that the failure of the emergency exit cover plate did not adversely affect the results of the test.

Table 4.1. Weapon simulation summary.

GAGE	Best Fit W, KT	Best Fit Pso, PSI	Best 8-KT Fit Pso, PSI
AB-2	3.4	171	139
AB-3	1.6	231	156
AVERAGE	2.4	198	148

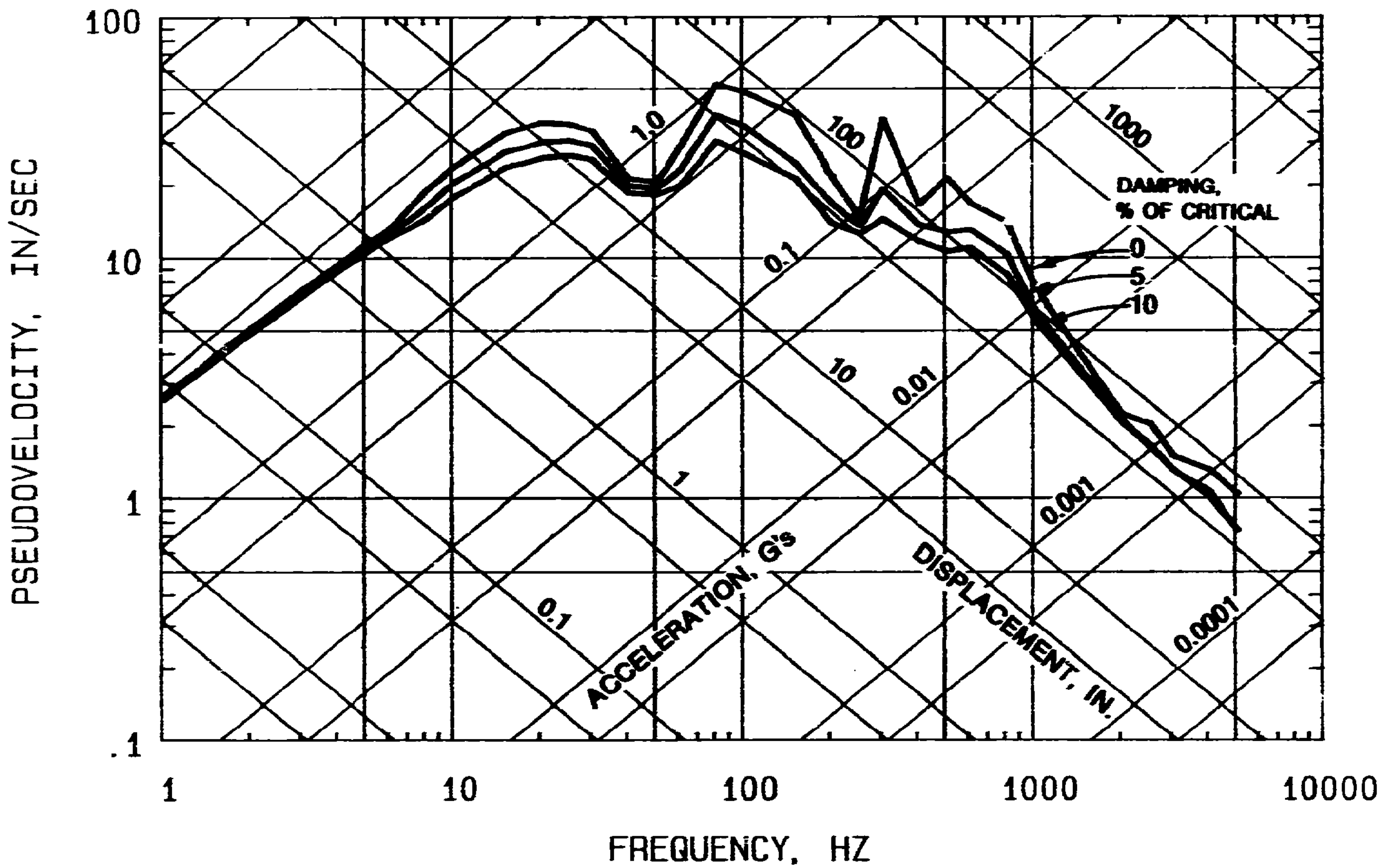


Figure 4.1. Shock spectra using accelerometer A3.

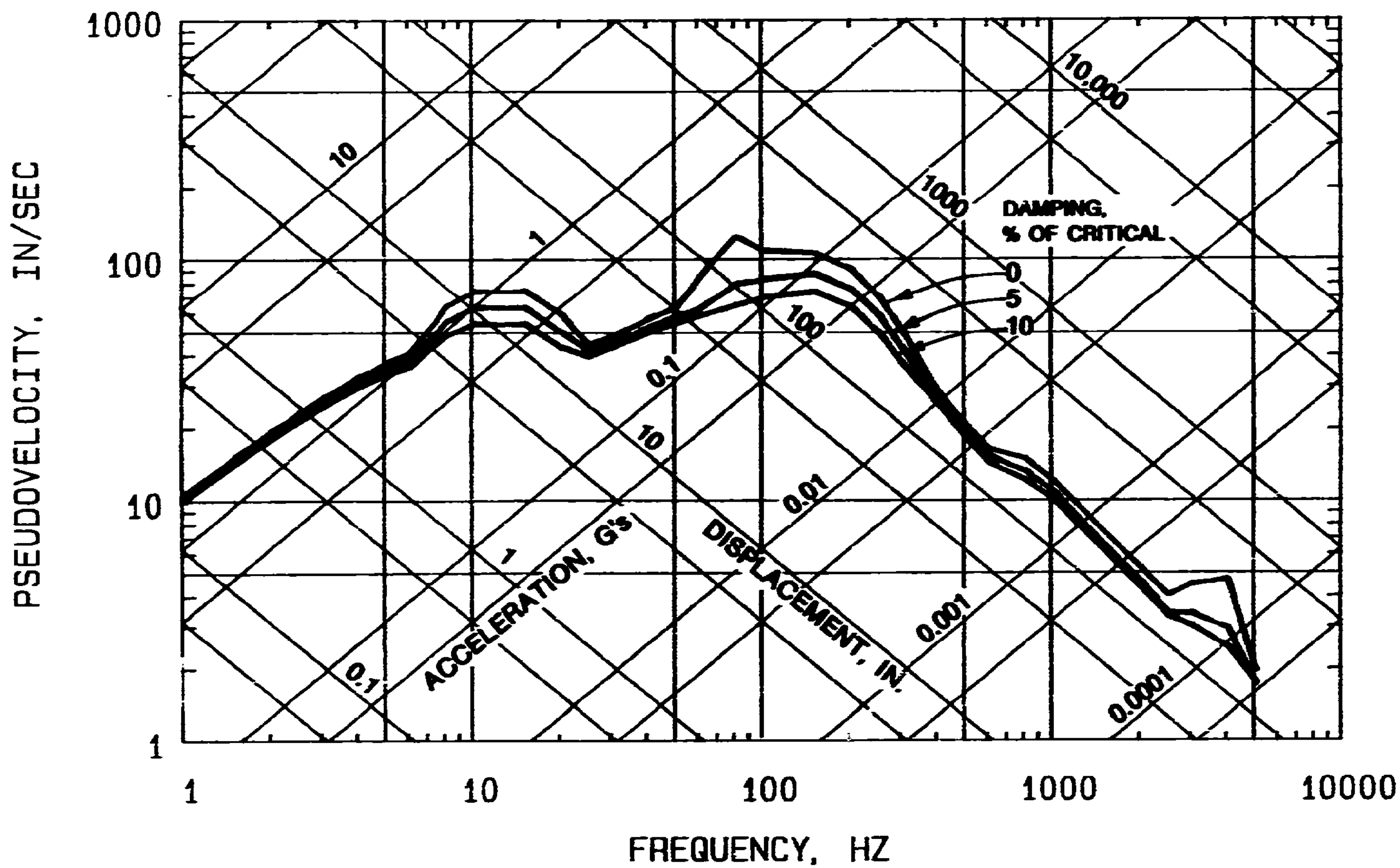


Figure 4.2. Shock spectra using accelerometer A5.

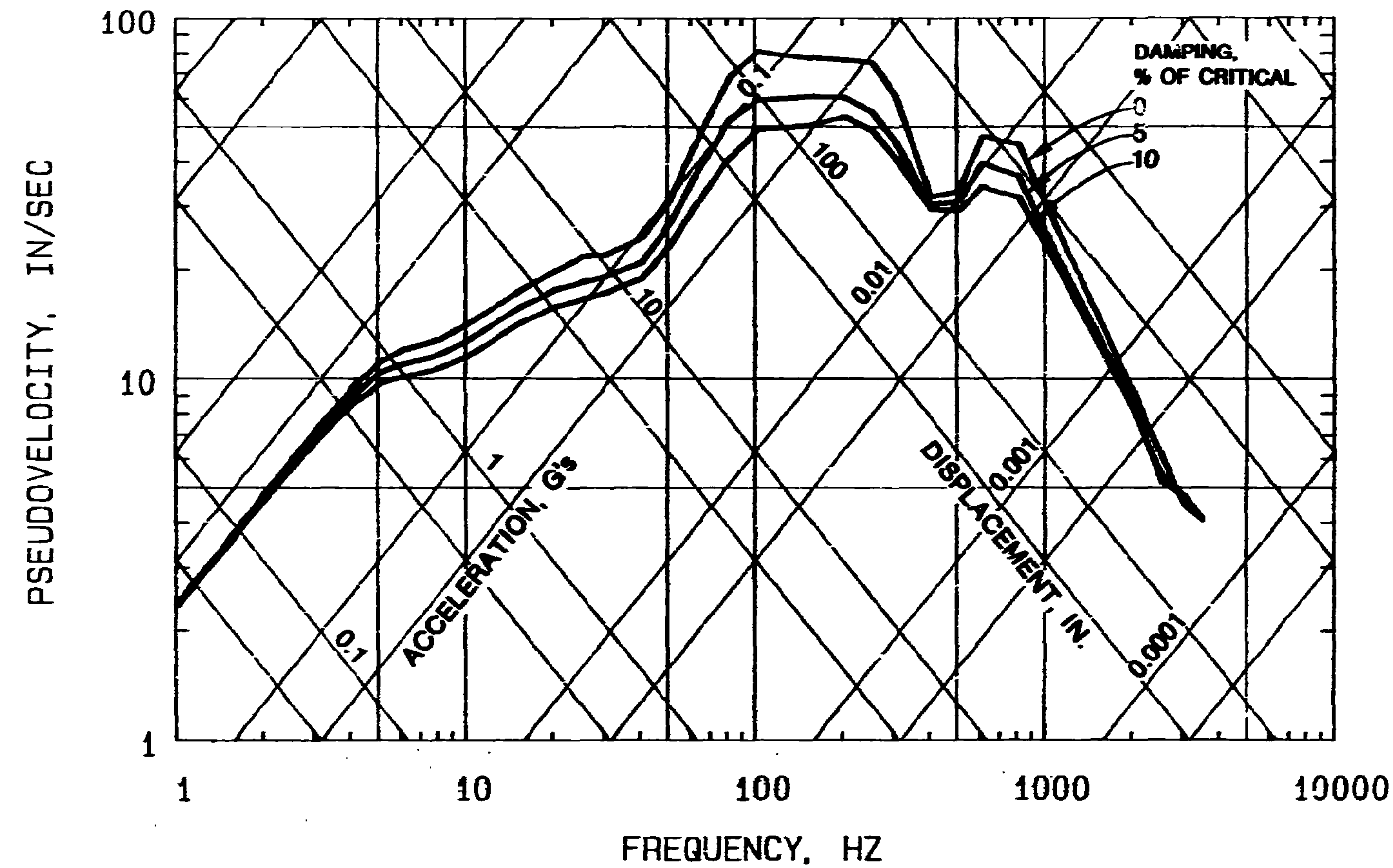


Figure 4.3. Shock spectra using accelerometer A7.

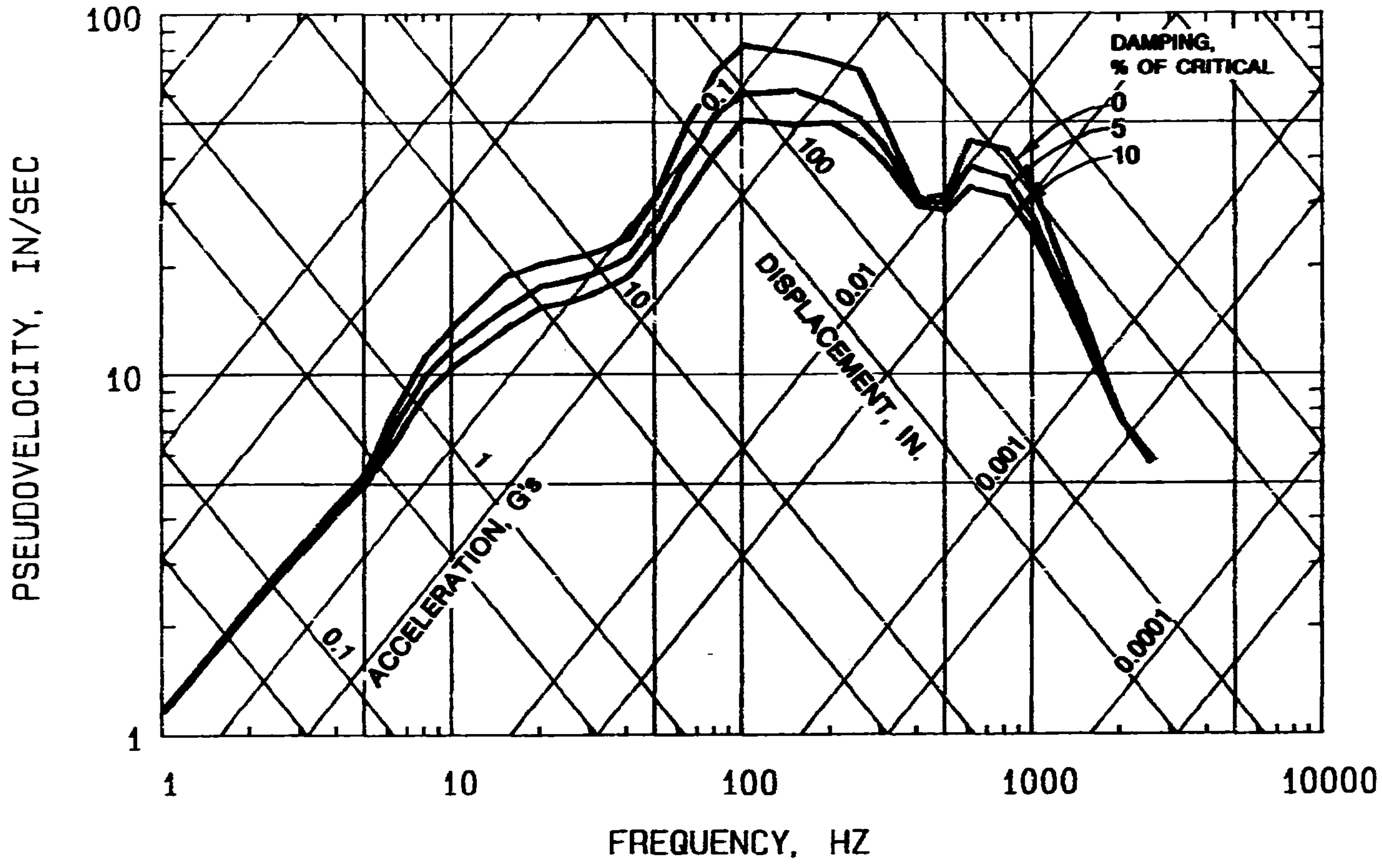


Figure 4.4. Shock spectra using accelerometer A12.

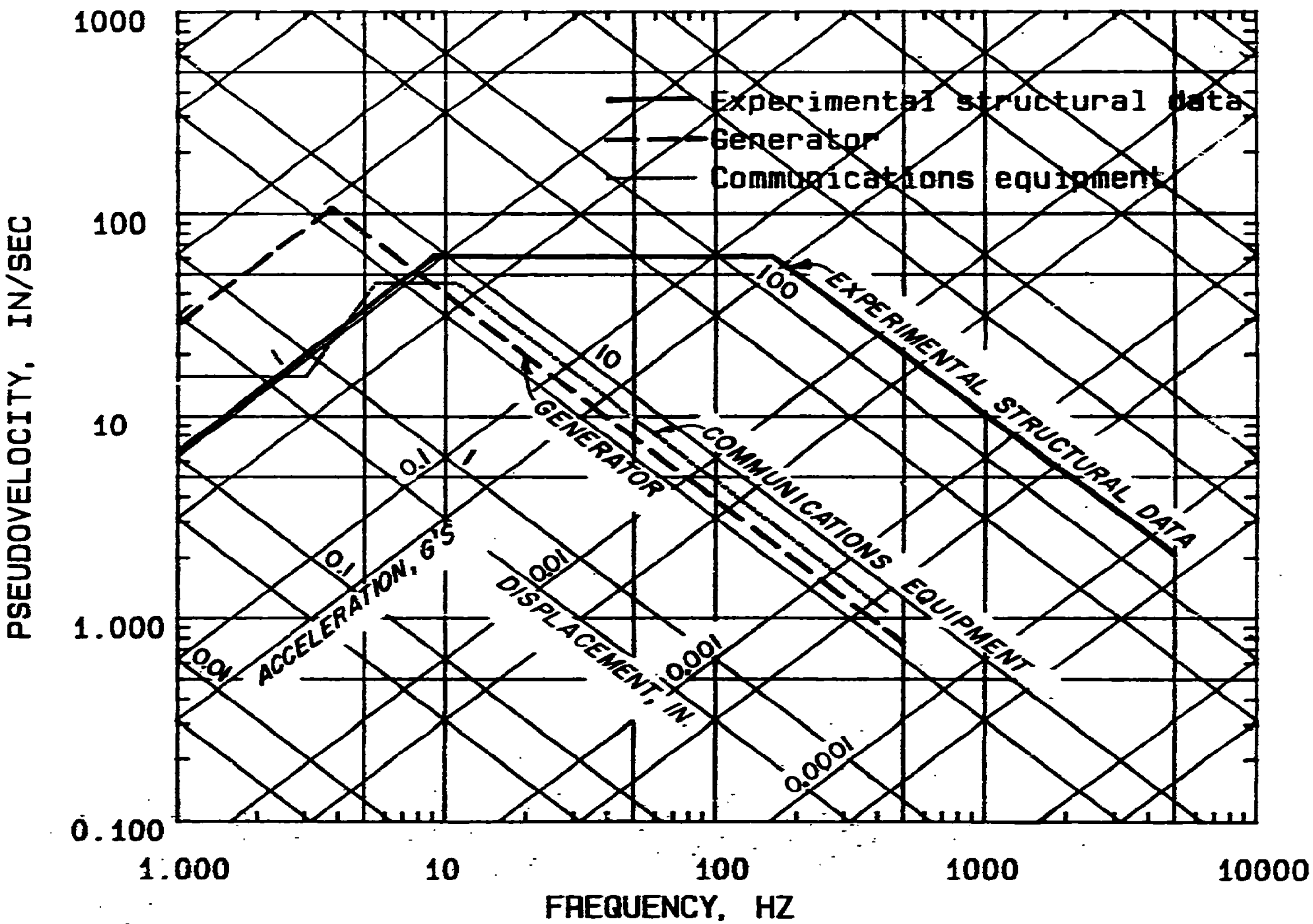


Figure 4.5. Comparison of the response spectra for the floor (10 percent damping) with fragility curves for typical floor-mounted equipment.

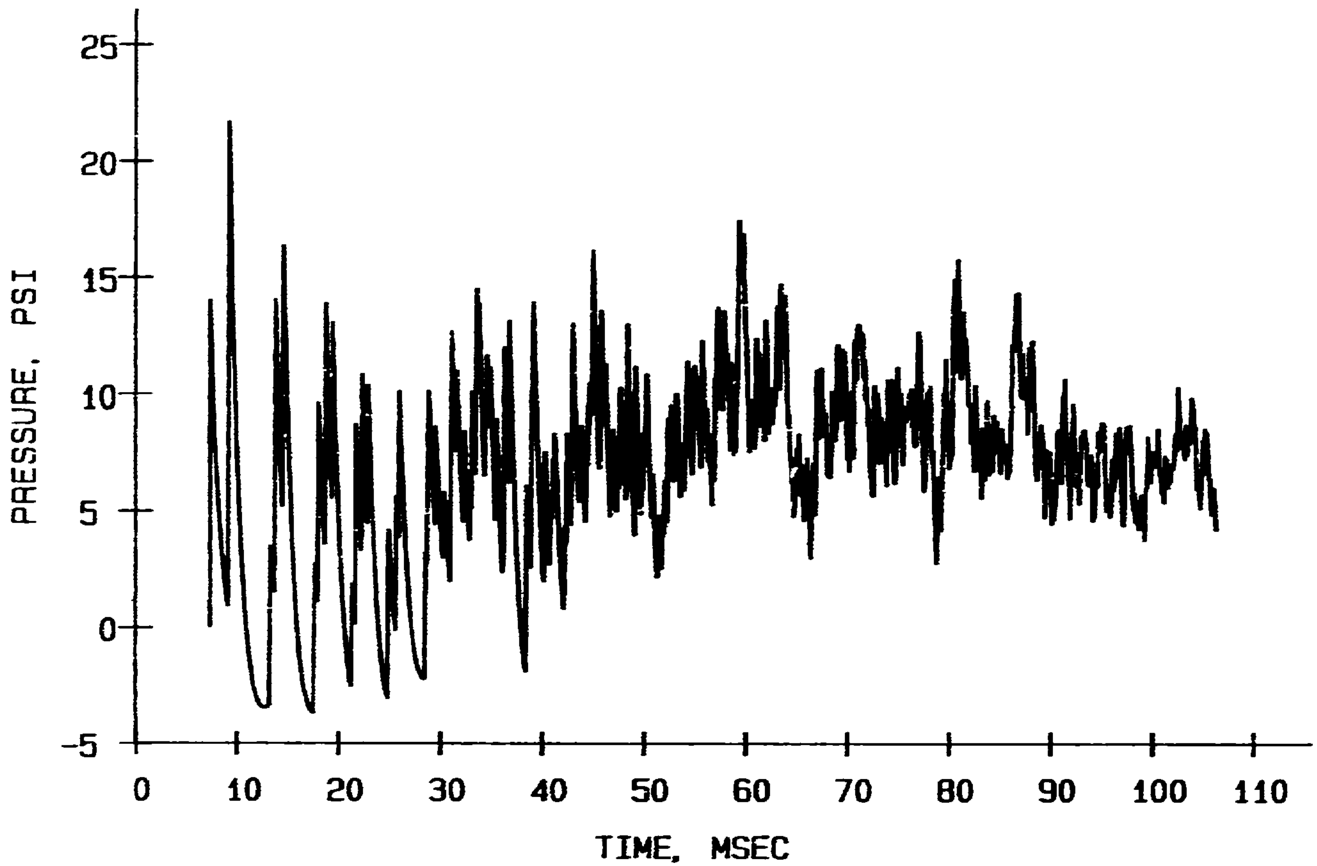


Figure 4.6. Pressure-time plot for target 1.

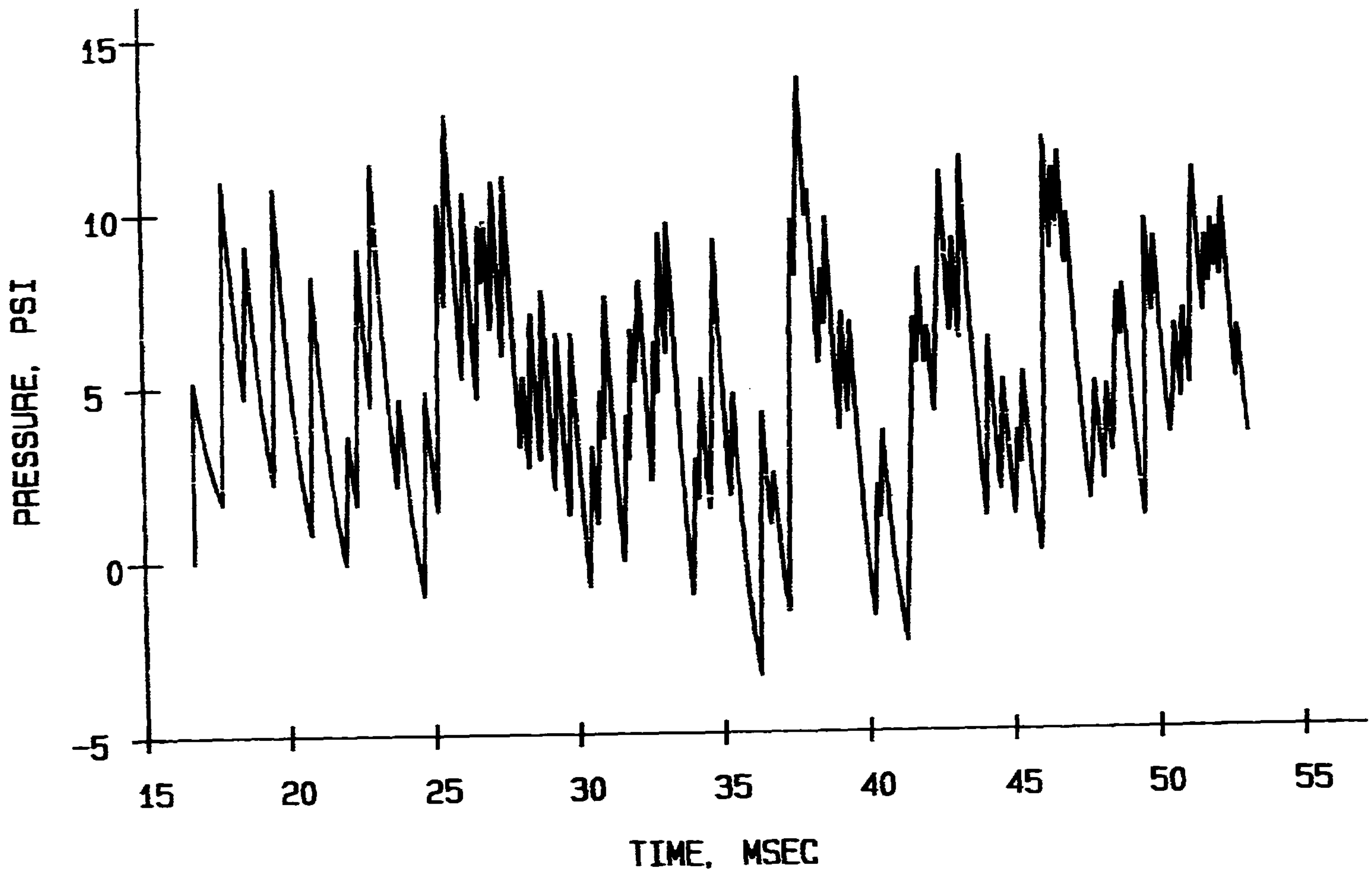


Figure 4.7. Pressure-time plot for target 2.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The MISTY PICTURE test of the 18-man shelter was a partially successful validation test of the modified structural design. Although the entryway, the entryway hatch, the intake and exhaust stacks, and the modified endwalls were damaged during the test, their designs proved to be adequate. The emergency exit cover plate was the only structural failure during this test. In-structure shock levels were survivable by equipment and personnel.

5.2 RECOMMENDATIONS

Shock isolation of shelter equipment is suggested to ensure equipment survivability. Padding of possible impact surfaces and/or restraint of shelter occupants is recommended as a precautionary measure to prevent impact injury.

The modifications to the structural design listed above should be incorporated in the final shelter design except for the emergency exit cover plate detail. The connection of this plate to the shelter barrel should be modified to prevent shearing of the bolts as the shelter undergoes moderate deformation during backfilling of the structure or during a dynamic loading. One alternate connection detail that should be investigated is slotted holes in the cover plate that would allow slipping of the cover plate relative to the shelter as the shelter deforms to reduce the tangential friction loading (shear) of the bolts. This detail should form a bearing-type connection rather than a combined-bearing and friction-type connection that currently exists.

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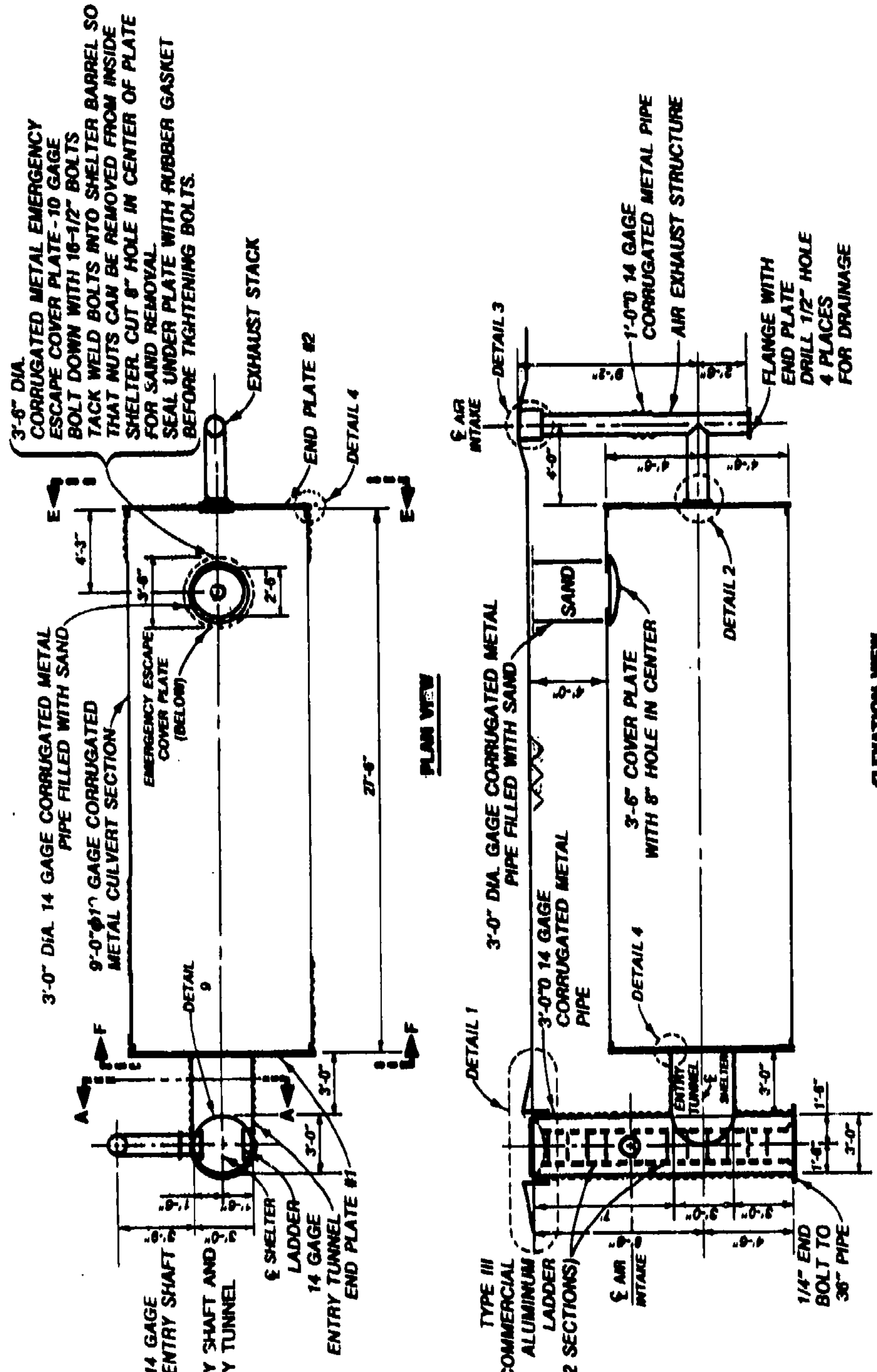
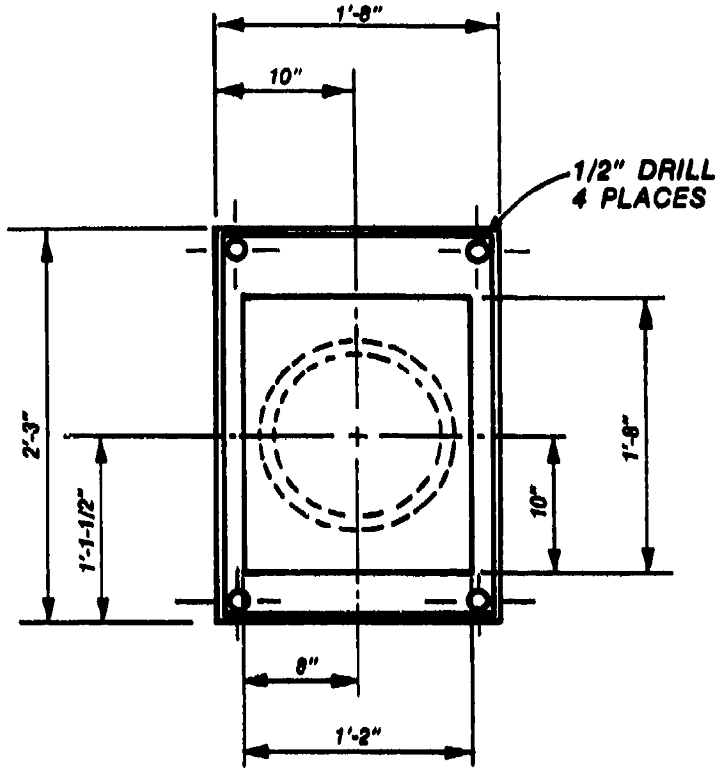
Woodson, S. C. and Slawson, T. R. 1986 (Dec). "Demonstration Test of the Keyworker Blast Shelter: MINOR SCALE," Technical Report SL-86-49, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

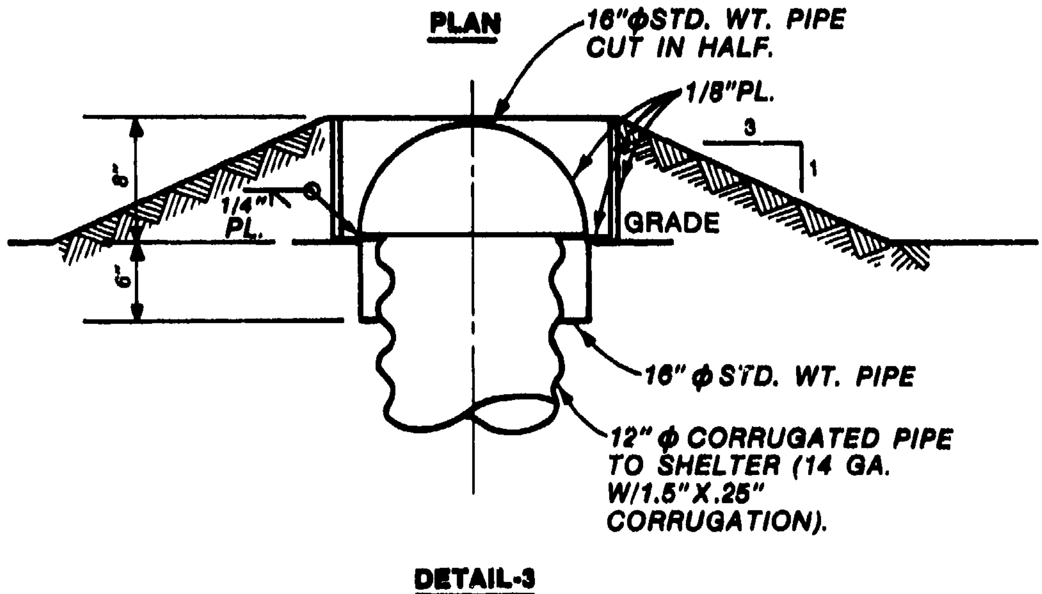
APPENDIX A

CONSTRUCTION DETAILS

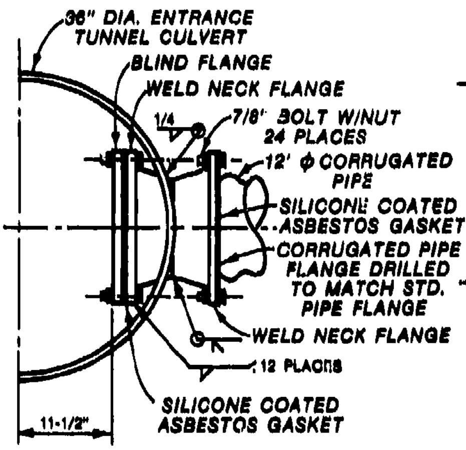

3'-6" DIA.
CORRUGATED METAL EMERGENCY ESCAPE COVER PLATE - 10 GAGE BOLT DOWN WITH 16-1/2" BOLTS TACK WELD BOLTS INTO SHELTER BARREL SO THAT NUTS CAN BE REMOVED FROM INSIDE SHELTER. CUT 8" HOLE IN CENTER OF PLATE FOR SAND REMOVAL. SEAL UNDER PLATE WITH RUBBER GASKET BEFORE TIGHTENING BOLTS.
EXHAUST STACK
END PLATE #2
DETAIL 4
3'-0" DIA. 14 GAGE CORRUGATED METAL PIPE FILLED WITH SAND
9'-0"Φ 1'' GAGE CORRUGATED METAL CULVERT SECTION
EMERGENCY ESCAPE COVER PLATE (BELOW)
DETAIL 9
27'-6"
PLAN VIEW
14 GAGE ENTRY SHAFT
℄ ENTRY SHAFT AND ℄ ENTRY TUNNEL
℄ SHELTER
LADDER
14 GAGE ENTRY TUNNEL
END PLATE #1
DETAIL 3
℄ AIR INTAKE
1'-0"Φ 14 GAGE CORRUGATED METAL PIPE
AIR EXHAUST STRUCTURE
FLANGE WITH END PLATE DRILL 1/2" HOLE 4 PLACES FOR DRAINAGE
3'-0" DIA. GAGE CORRUGATED METAL PIPE FILLED WITH SAND
SAND
3'-6" COVER PLATE WITH 8" HOLE IN CENTER
DETAIL 2
DETAIL 1
3'-0"Φ 14 GAGE CORRUGATED METAL PIPE
ENTRY TUNNEL
TYPE III COMMERCIAL ALUMINUM LADDER (2 SECTIONS)
1/4" END BOLT TO 36" PIPE
ELEVATION VIEW



PLAN

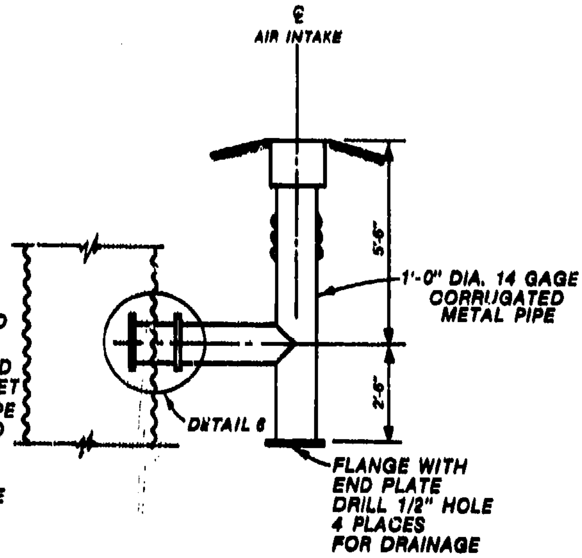


DETAIL-3

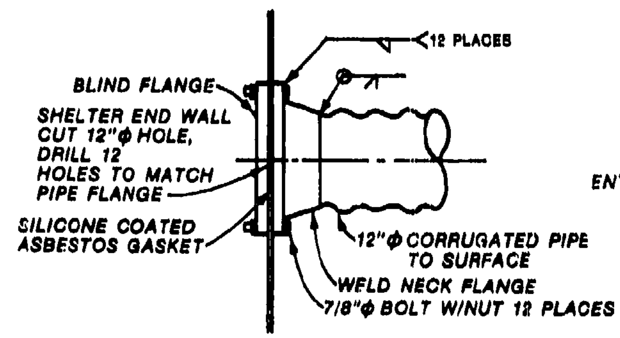


DETAIL-6

(INTAKE STACK TO ENTRYWAY)

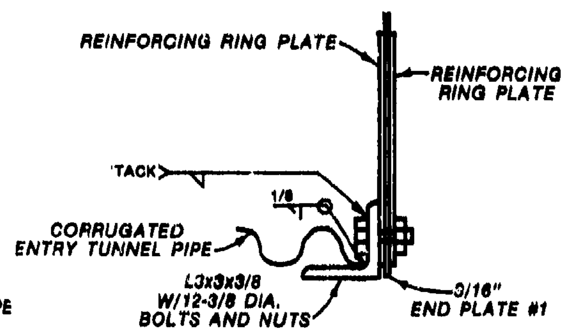


SECTION A-A



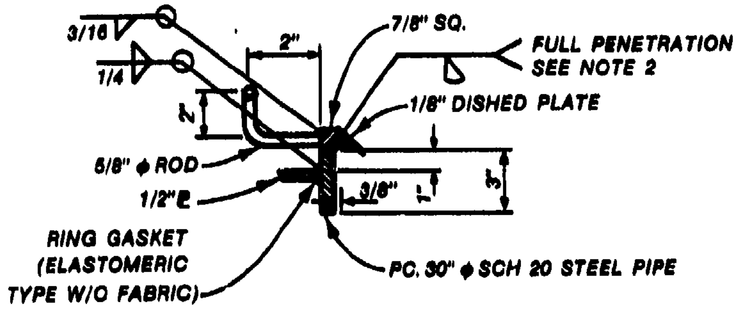
DETAIL-2

(EXHAUST STACK TO END WALL)

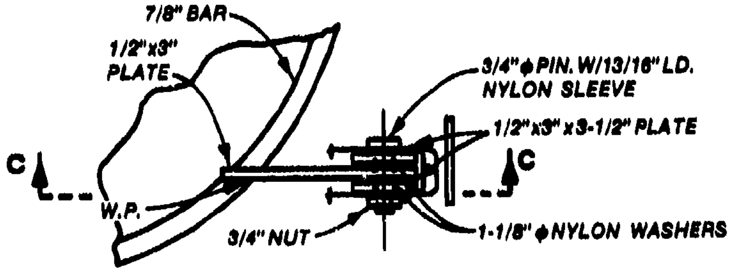


DETAIL-4

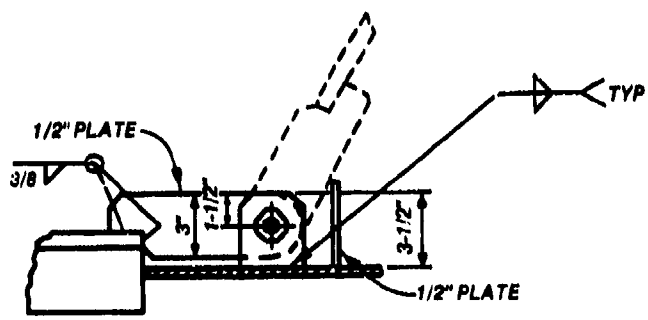
(END WALL TO ENTRYWAY)



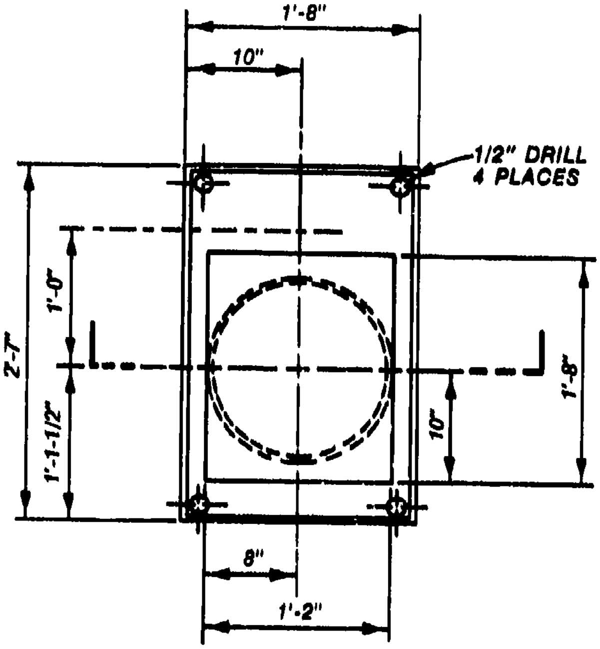
DETAIL 7



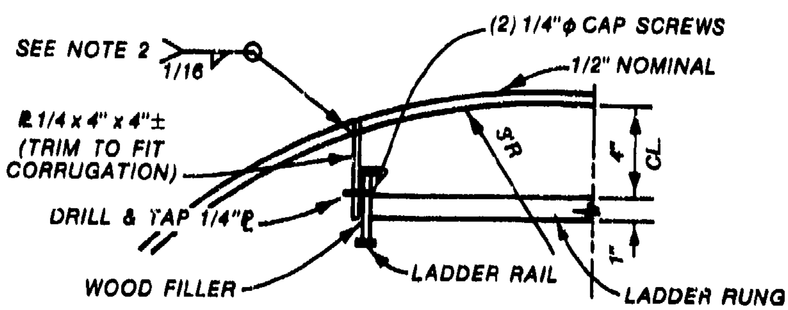
DETAIL 8



SECTION C-C

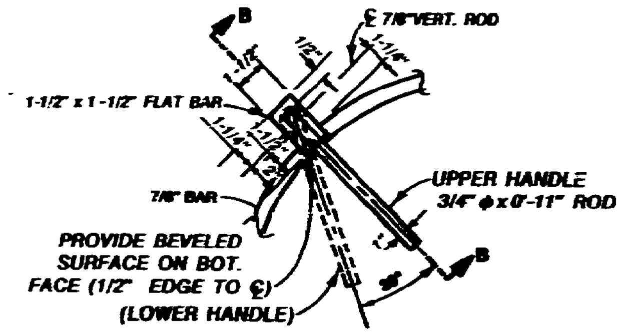


DETAIL 10

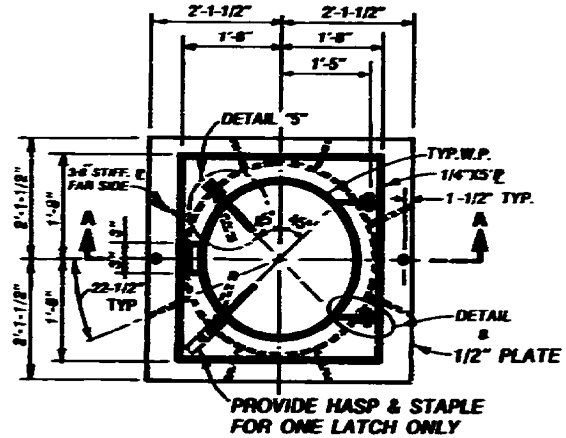


LADDER SECTIONS TO BE CONNECTED
TOP AND BOTTOM EACH SIDE

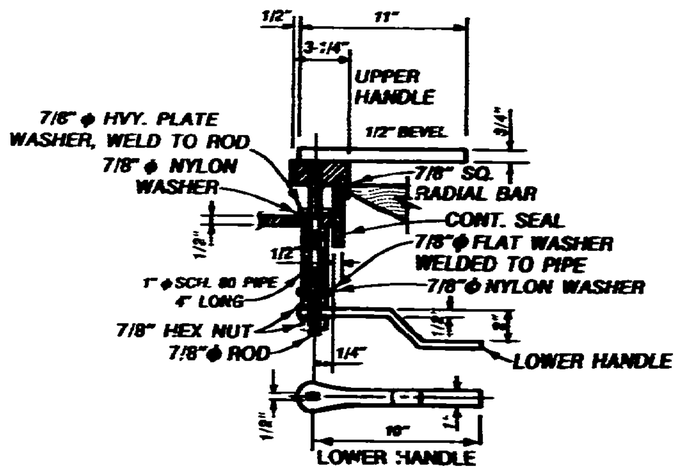
DETAIL 9



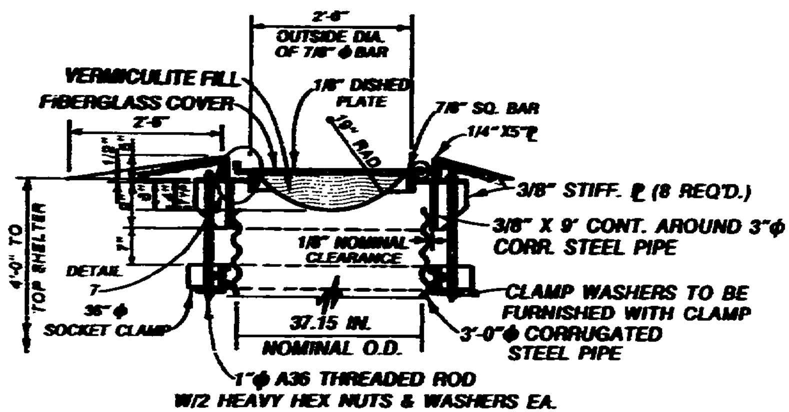
DETAIL-5



PLAN

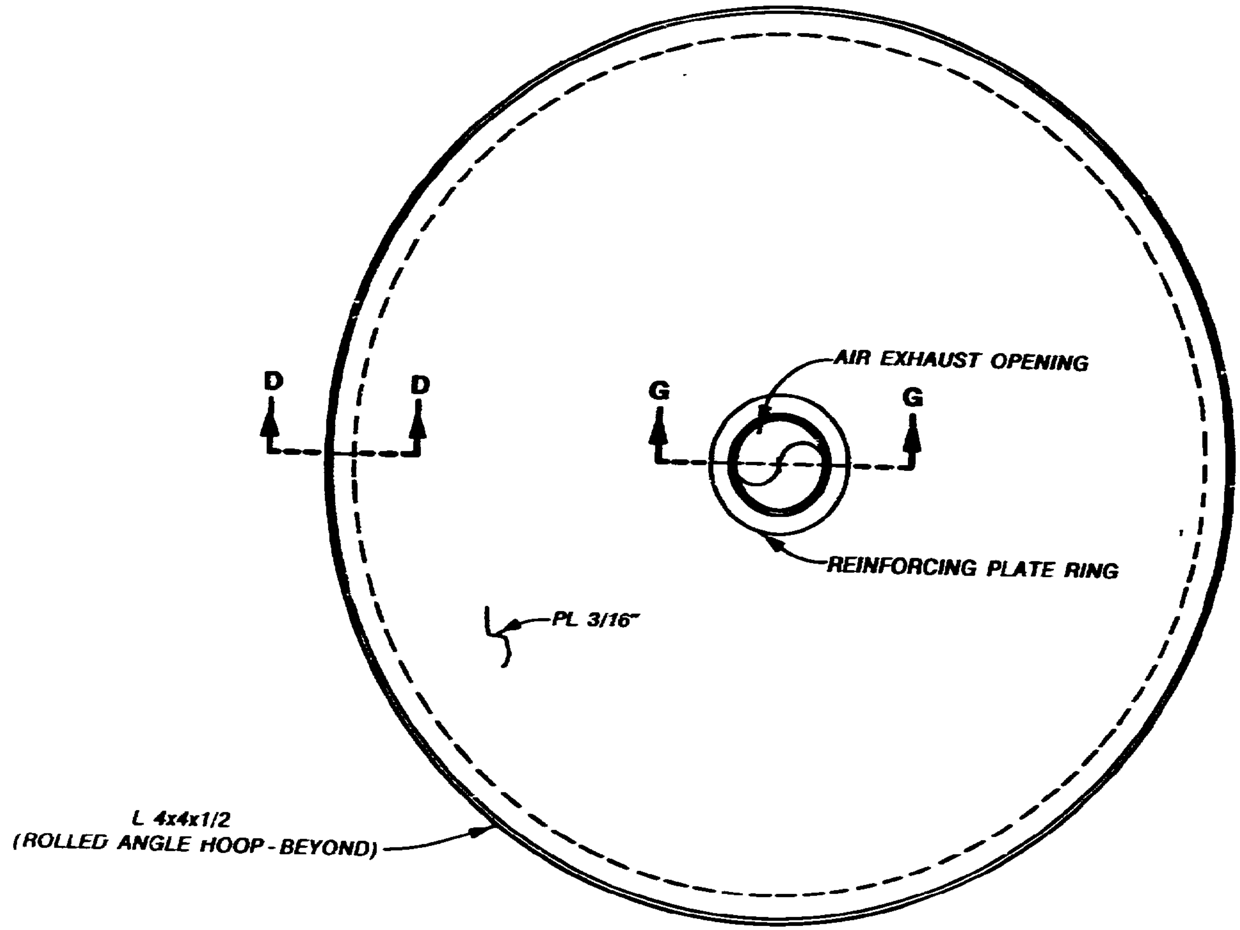


SECTION B-B

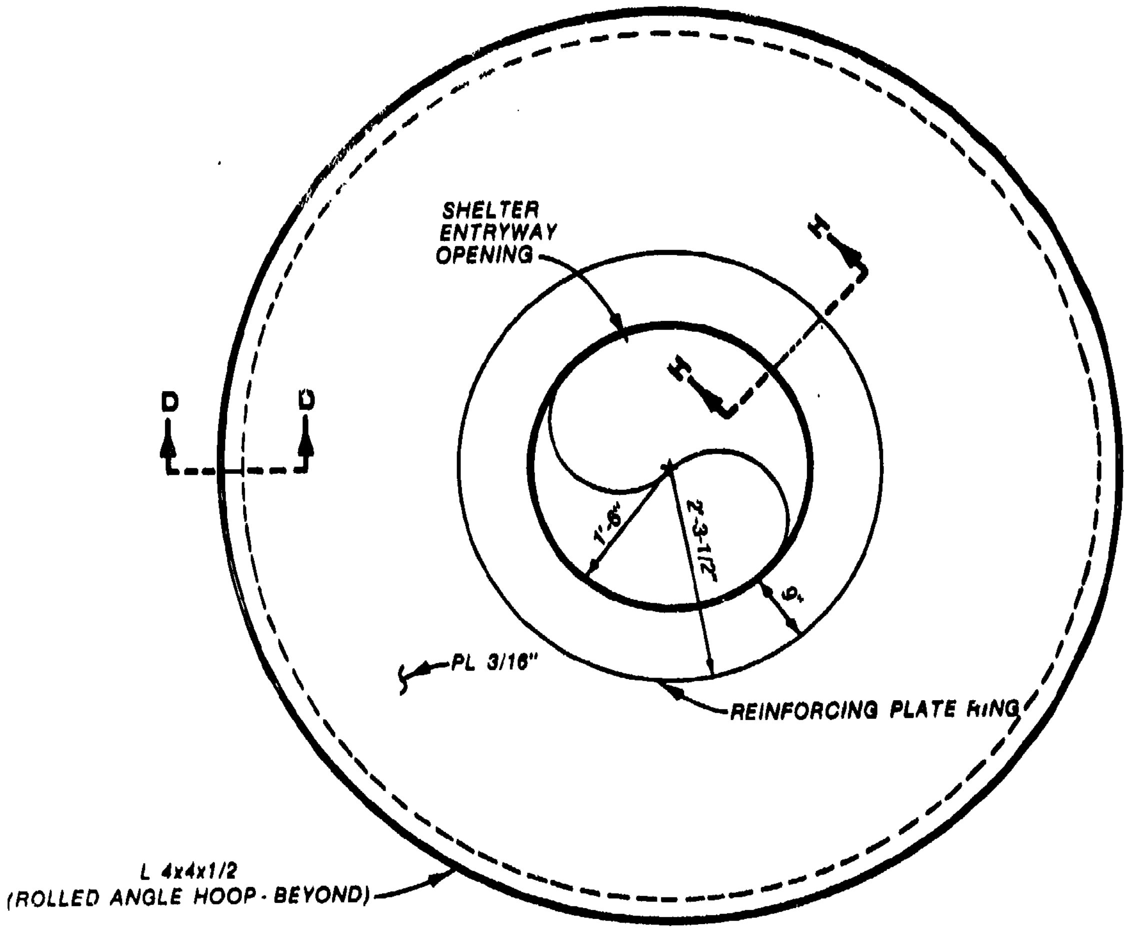


DETAIL-1

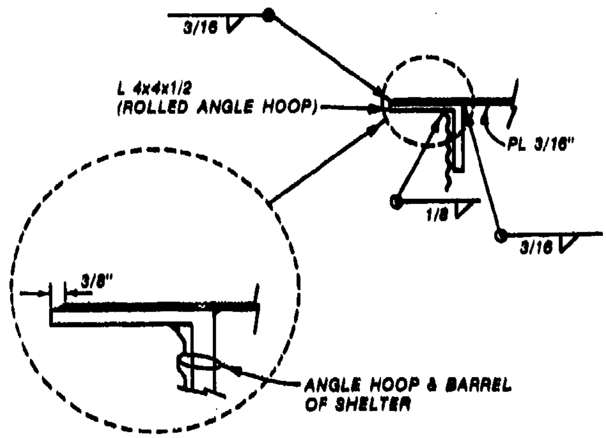
(ENTRYWAY HATCH)


AIR EXHAUST OPENING
D
D
G
G
REINFORCING PLATE RING
PL 3/16"
L 4x4x1/2
(ROLLED ANGLE HOOP - BEYOND)

SECTION E-E


SHELTER
ENTRYWAY
OPENING
D
D
H
H
1'-6"
2'-3-1/2"
9"
PL 3/16"
REINFORCING PLATE RING
L 4x4x1/2
(ROLLED ANGLE HOOP - BEYOND)

SECTION F-F



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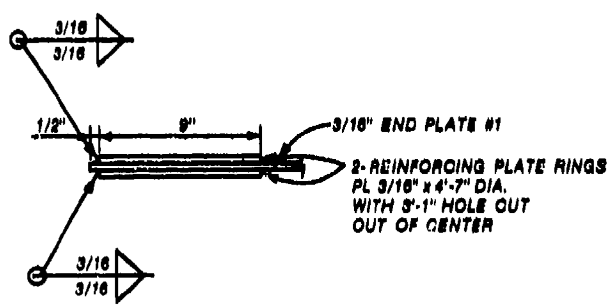
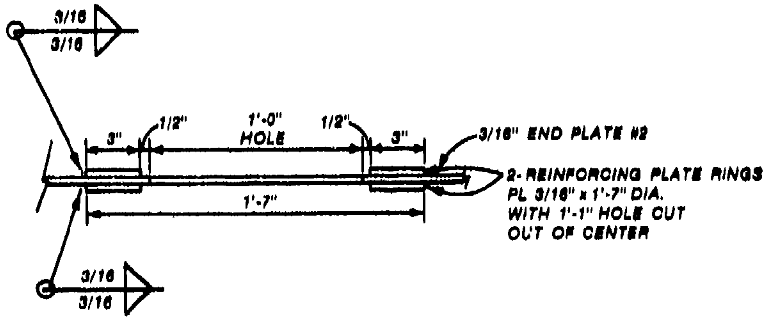


SECTION H-H



SECTION G-G

APPENDIX B

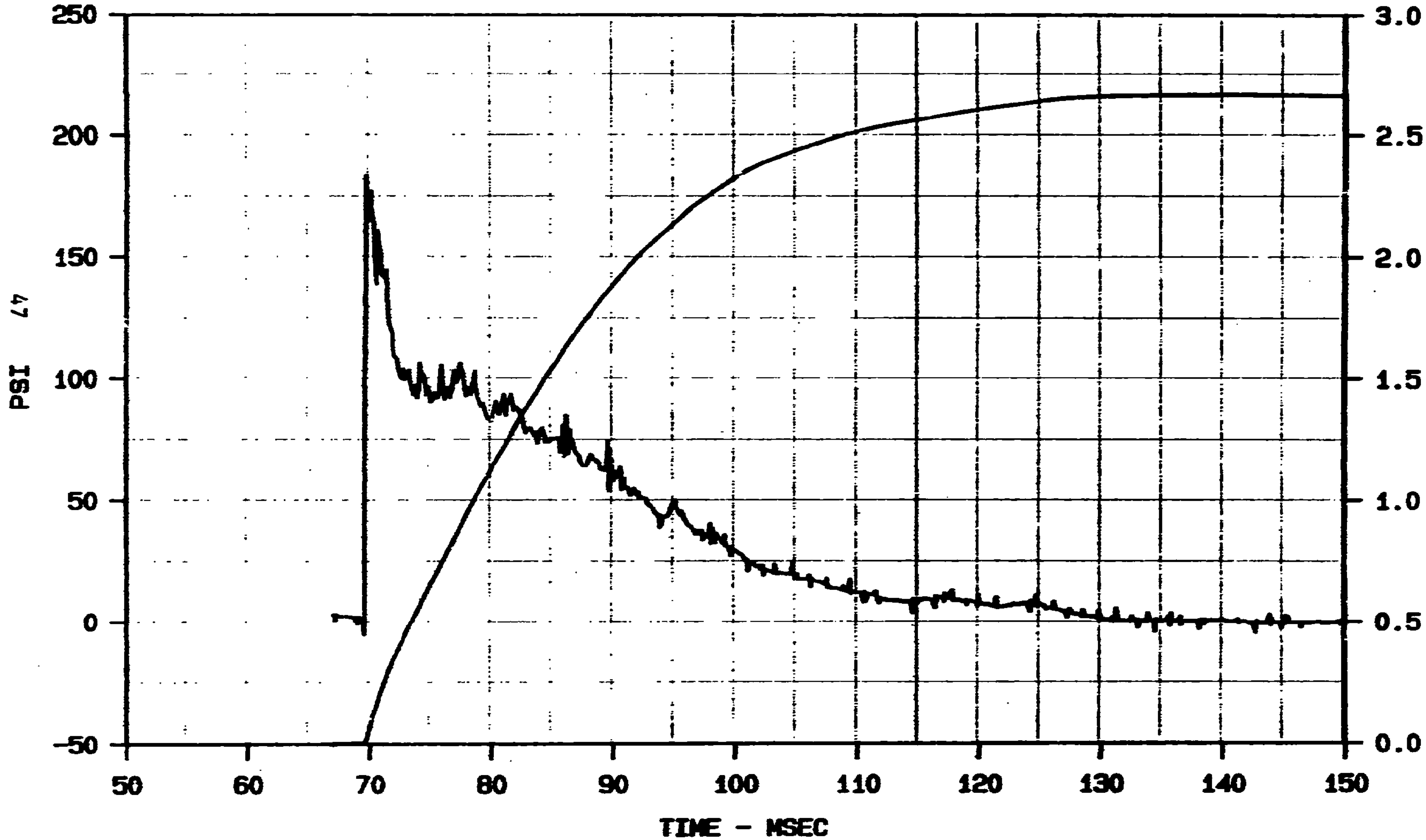
TEST DATA

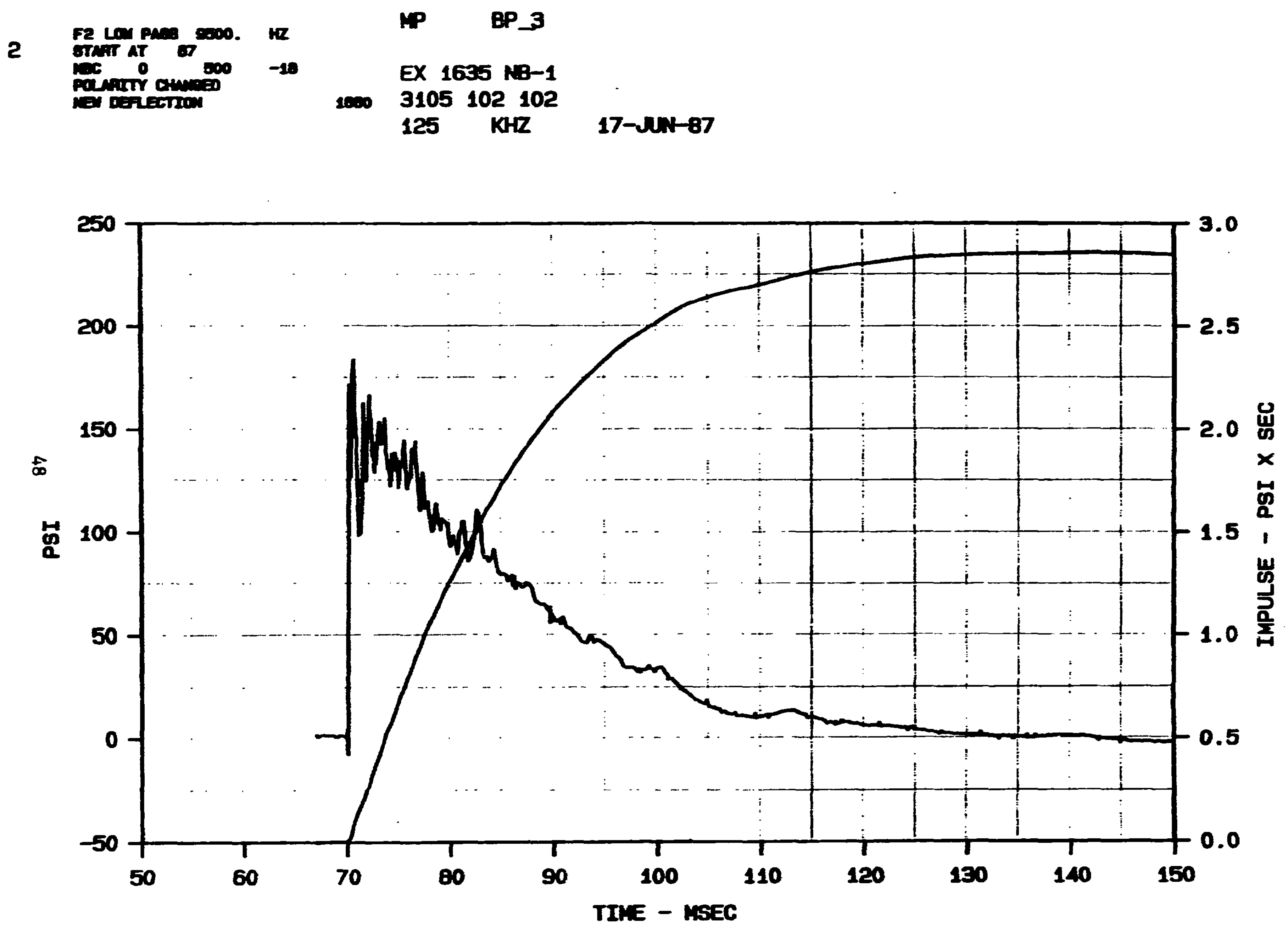
1

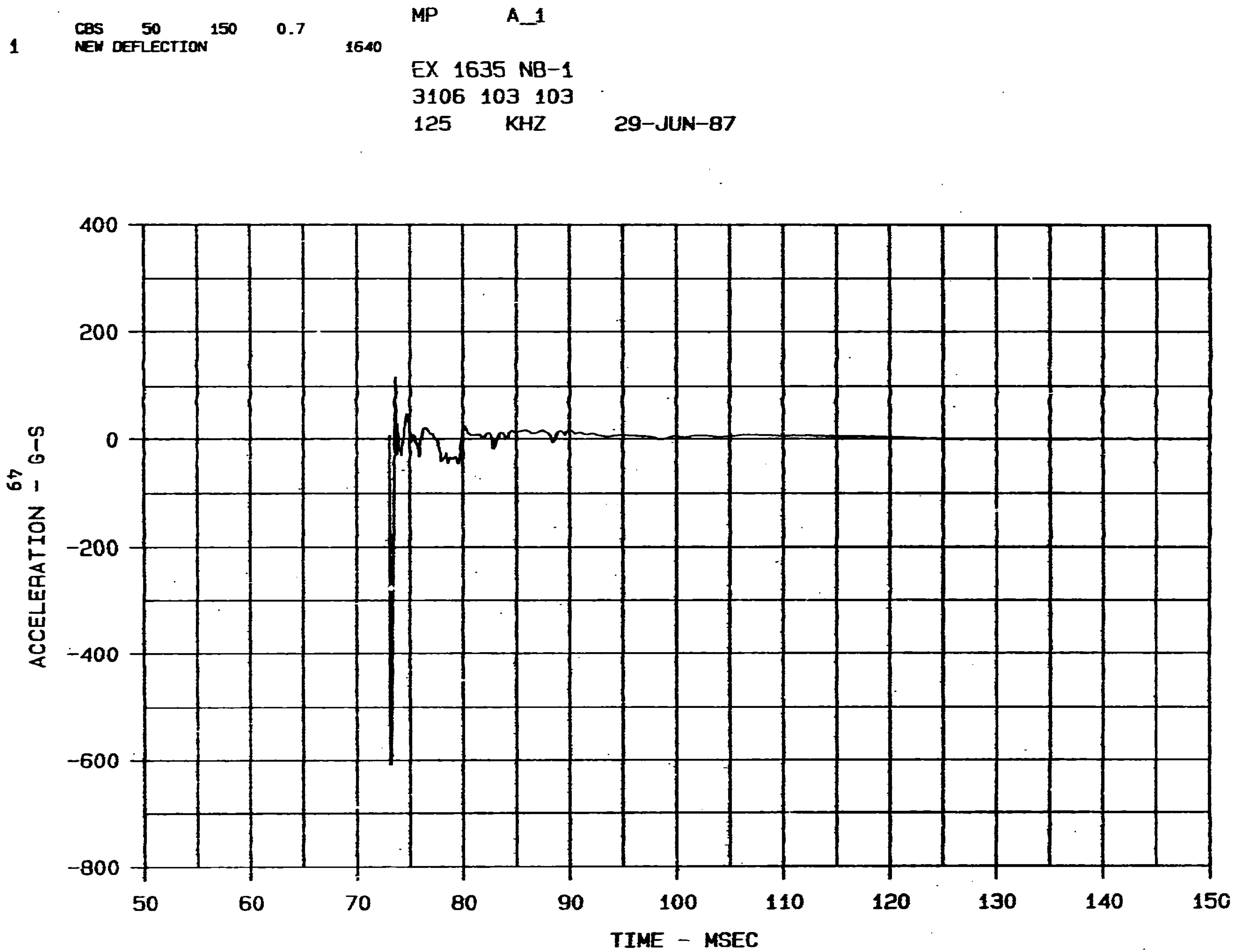
F2 LOW PASS 9500. HZ
START AT 67
MSC 0 500 -15
POLARITY CHANGED
NEW DEFLECTION 1650

MP BP_2

EX 1635 NB-1
3104 101 101
125 KHZ 17-JUN-87



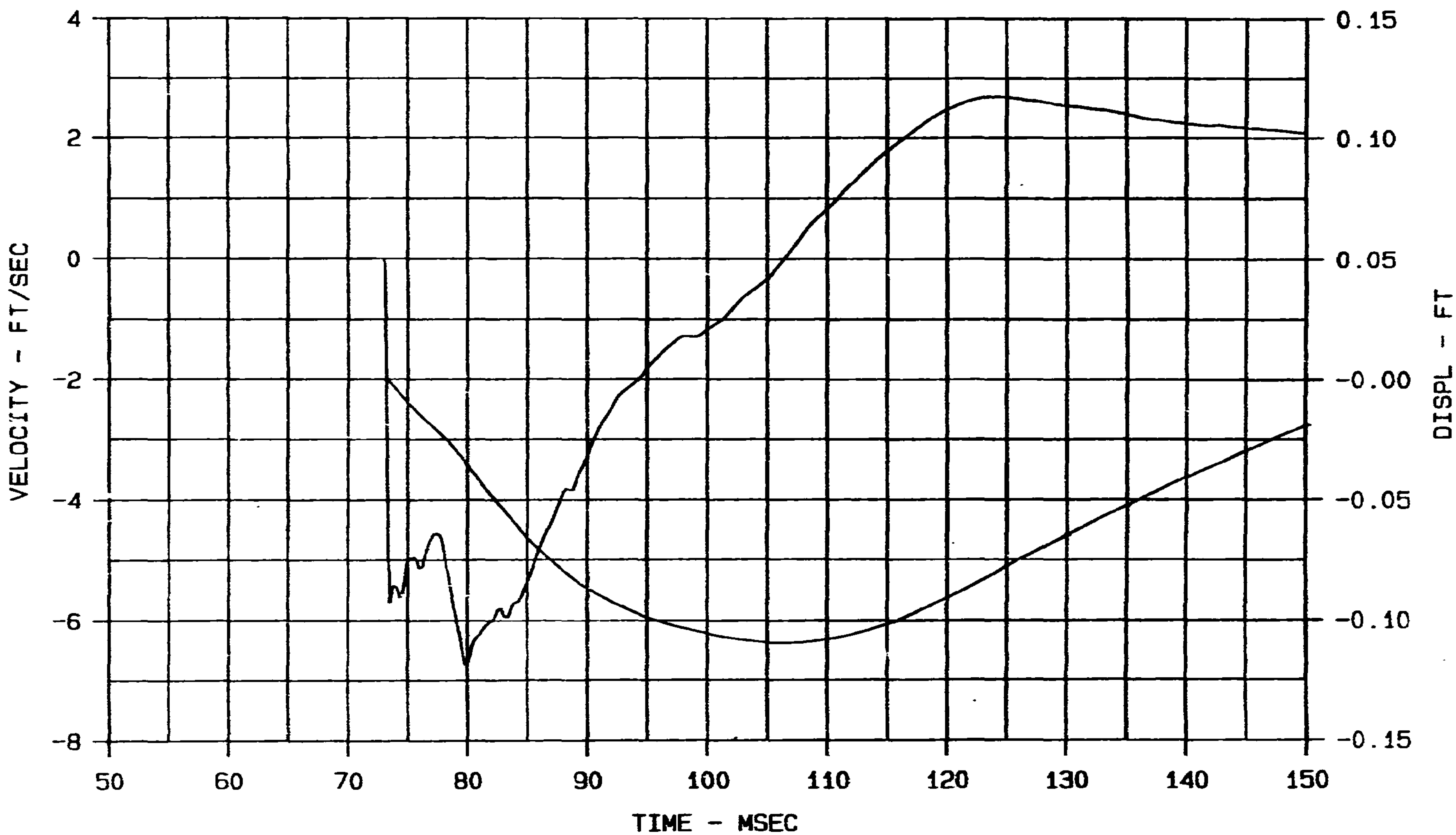

2
F2 LOW PASS 9500. HZ
START AT 87
NBC 0 500 -18
POLARITY CHANGED
NEW DEFLECTION 1000
MP BP_3
EX 1635 NB-1
3105 102 102
125 KHZ 17-JUN-87
PSI
250
200
150
100
50
0
-50
IMPULSE - PSI X SEC
3.0
2.5
2.0
1.5
1.0
0.5
0.0
50
60
70
80
90
100
110
120
130
140
150
TIME - MSEC


CBS 50 150 0.7
1 NEW DEFLECTION 1640
MP A_1
EX 1635 NB-1
3106 103 103
125 KHZ 29-JUN-87
400
200
0
-200
-400
-600
-800
50
60
70
80
90
100
110
120
130
140
150
TIME - MSEC
ACCELERATION - G-S

2 CBS 50 150 0.7
NEW DEFLECTION 1640

MP A_1

EX 1635 NB-1
3106 103 103
125 KHZ 29-JUN-87



5 CBS 50 150 0.33 NEW DEFLECTION 1050

MP A_2

EX 1635 NB-1
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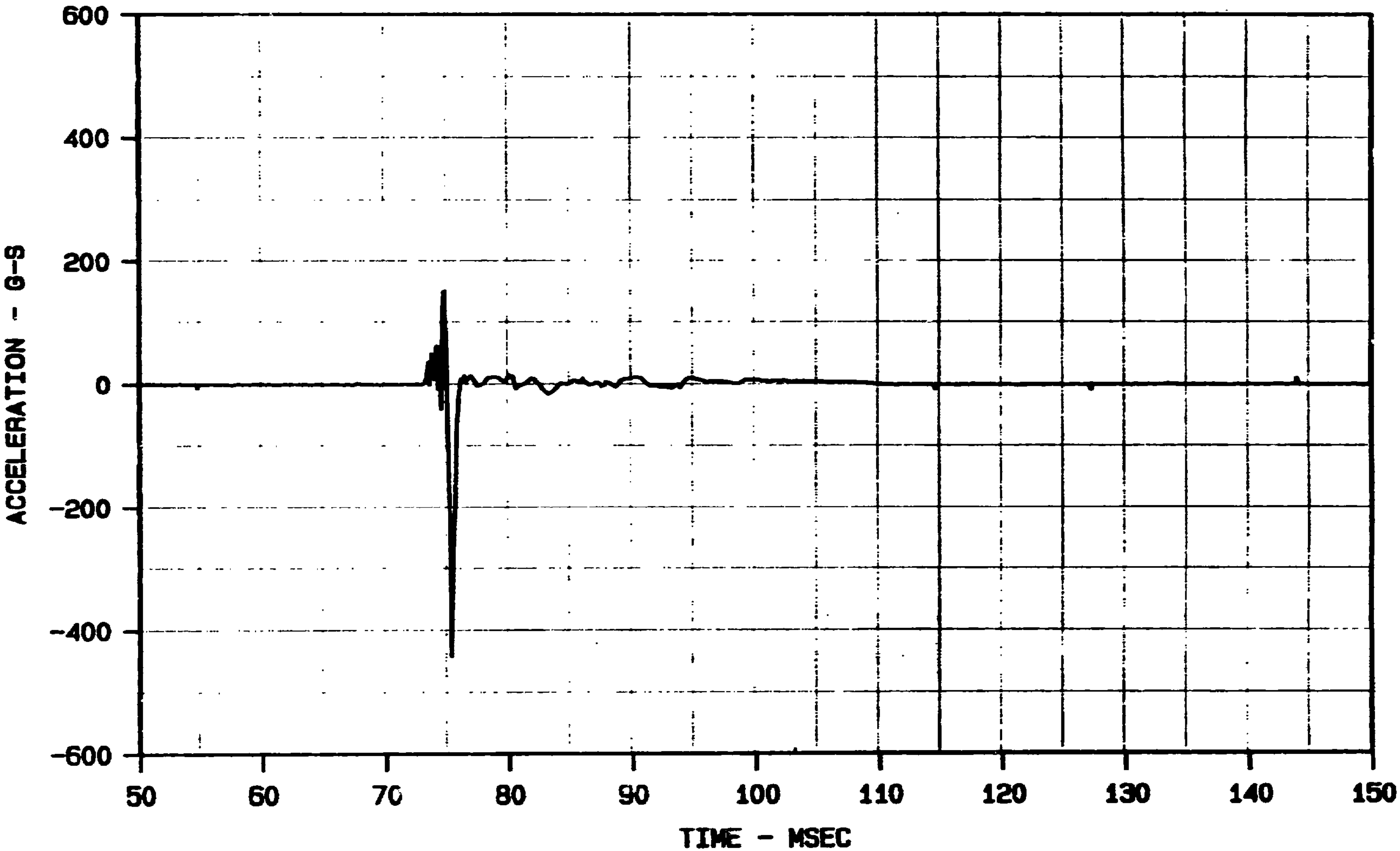
125 KHZ 17-JUN-87



6 CBS 80 150 0.63 NEW DEFLECTION 1650

MP A_2

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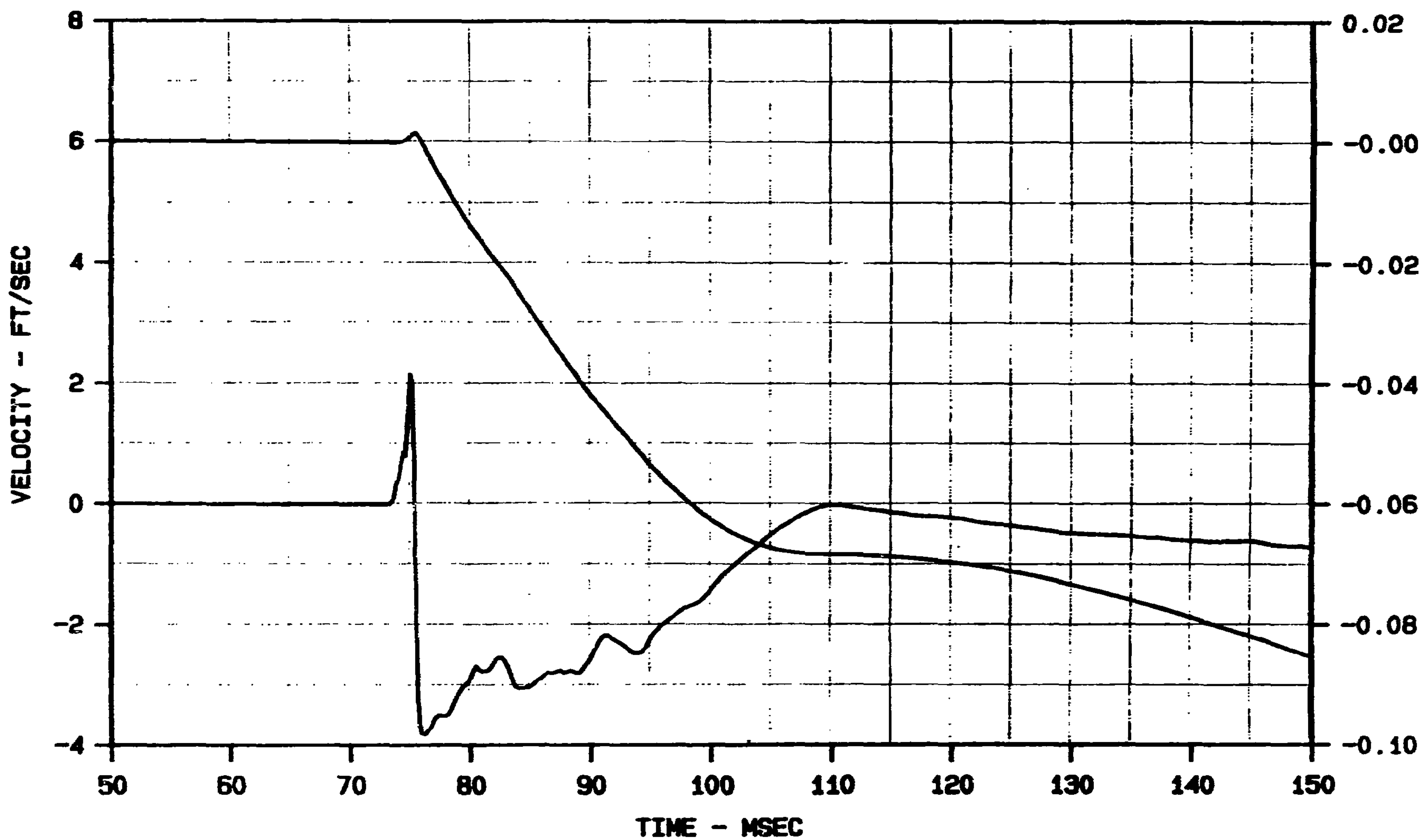
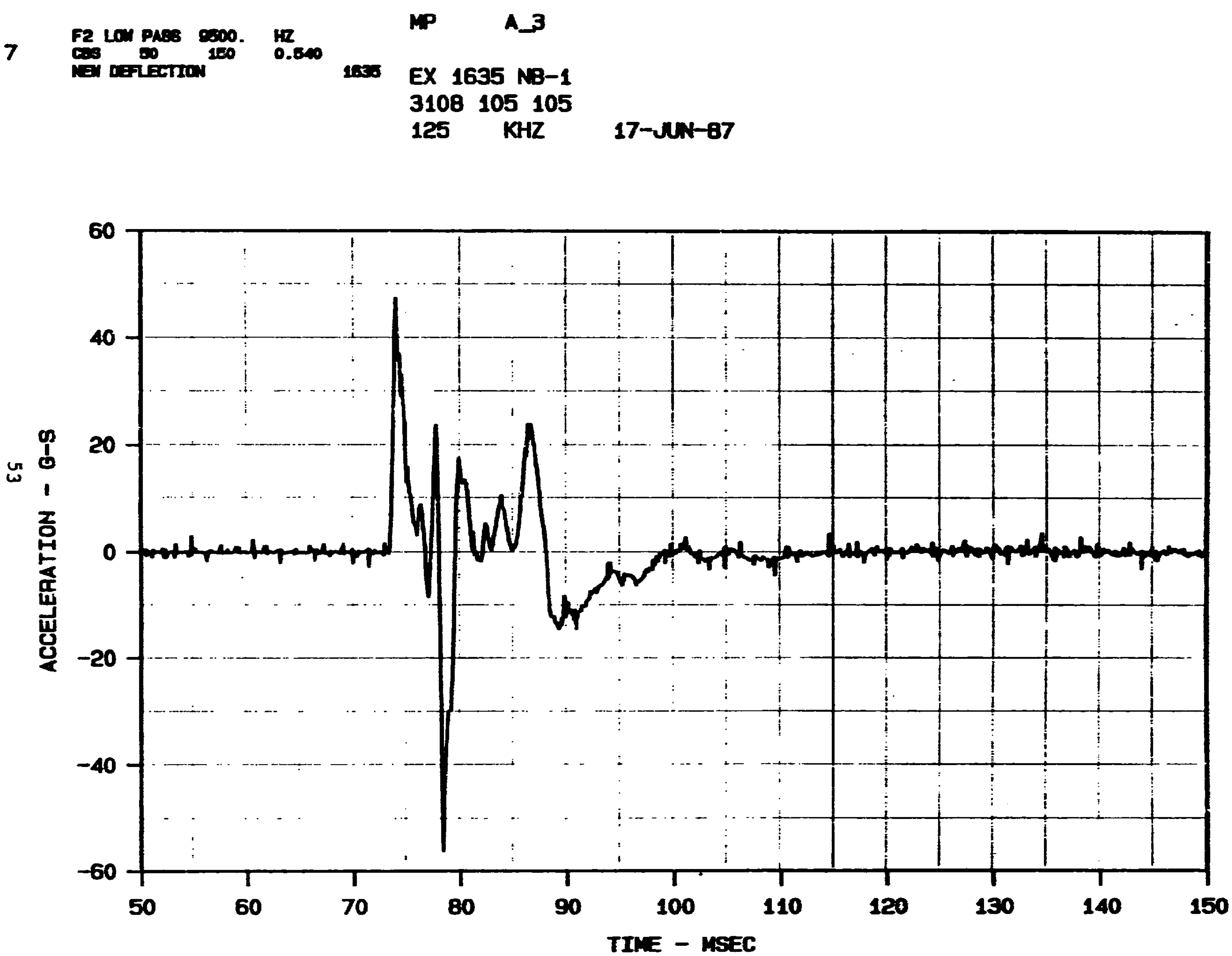
125 KHZ 17-JUN-87





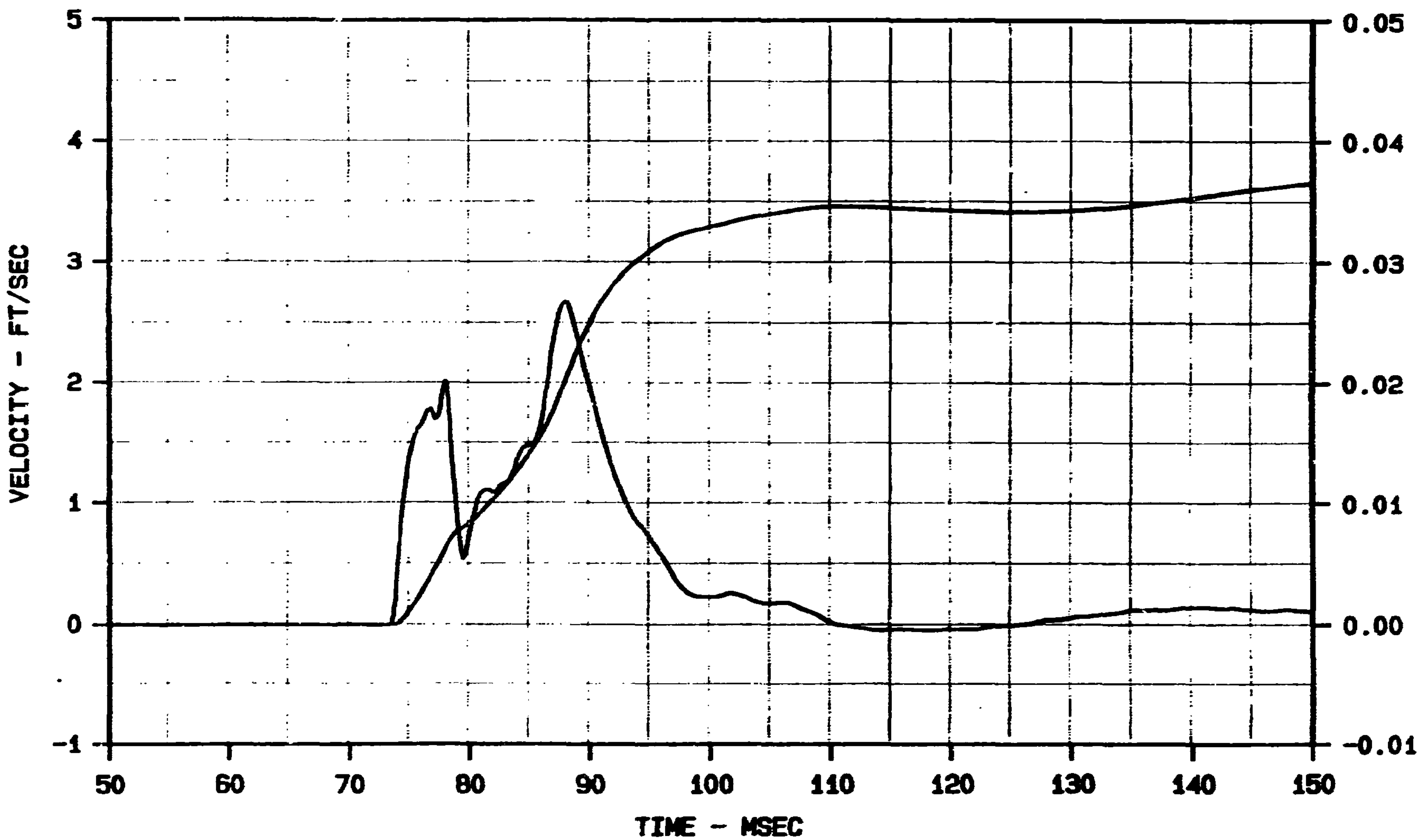
7
F2 LOW PASS 9500. HZ
CBS 50 150 0.540
NEW DEFLECTION 1635
MP A_3
EX 1635 NB-1
3108 105 105
125 KHZ 17-JUN-87
ACCELERATION - G-S
60
40
20
0
-20
-40
-60
50
60
70
80
90
100
110
120
130
140
150
TIME - MSEC

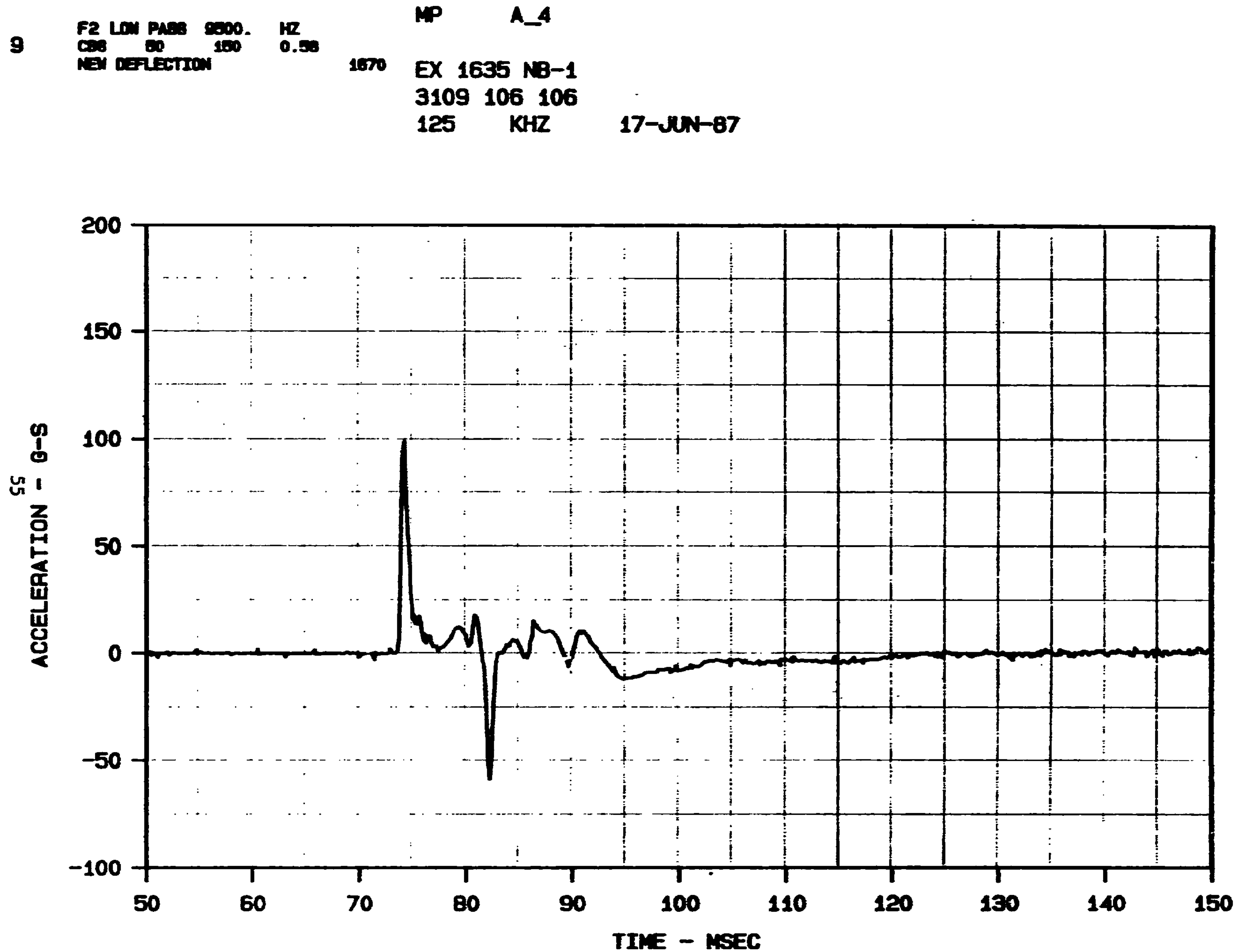
8

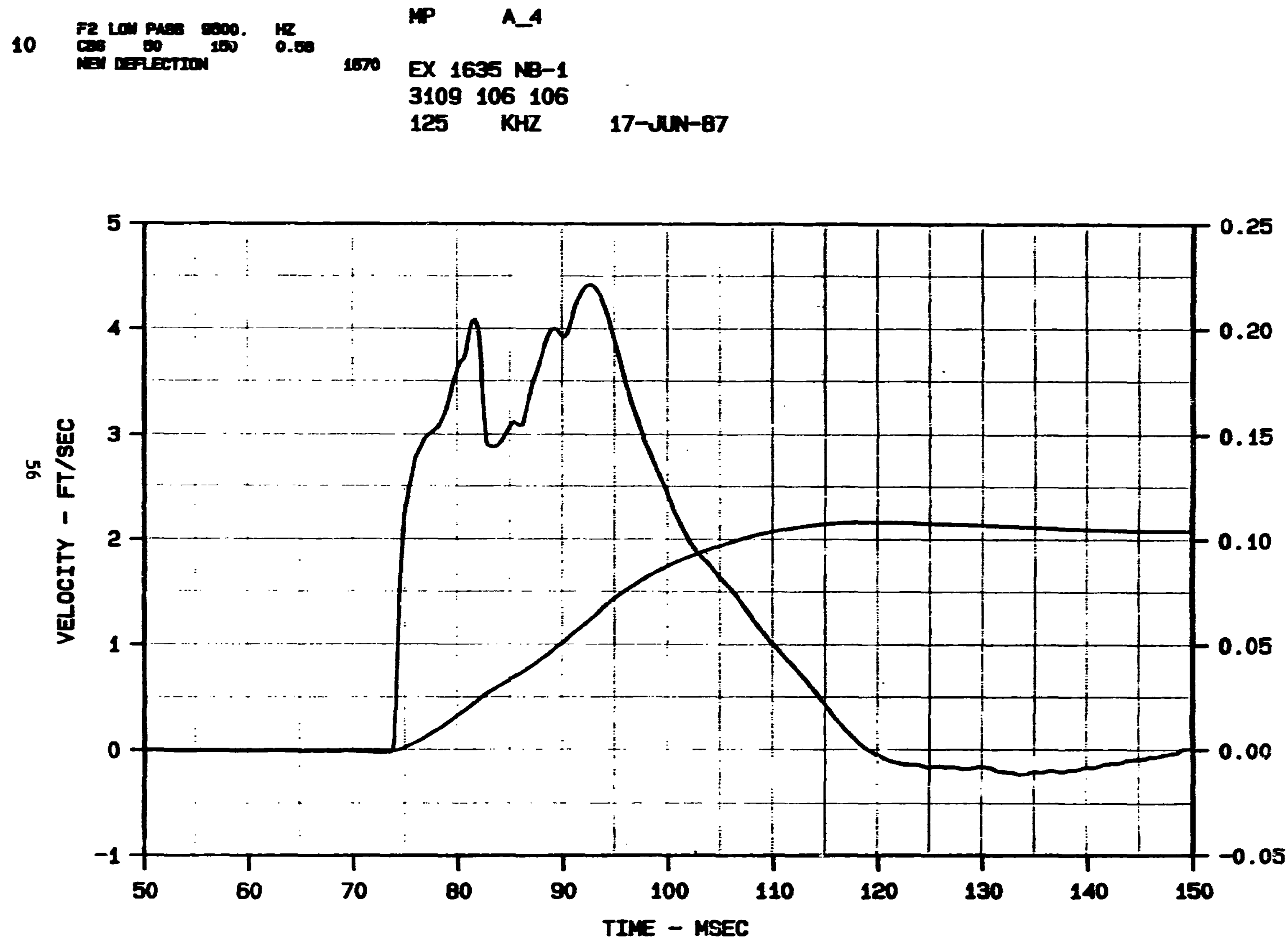
F2 LOW PASS 9500. HZ
CBS 50 150 0.540
NEW DEFLECTION 1635

MP A_3

EX 1635 NB-1
3108 105 105
125 KHZ 17-JUN-87




9
F2 LOW PASS 9500. HZ
C86 80 150 0.58
NEW DEFLECTION 1670
MP A_4
EX 1635 NB-1
3109 106 106
125 KHZ 17-JUN-87
200
150
100
50
0
-50
-100
ACCELERATION - G-S
50
60
70
80
90
100
110
120
130
140
150
TIME - MSEC

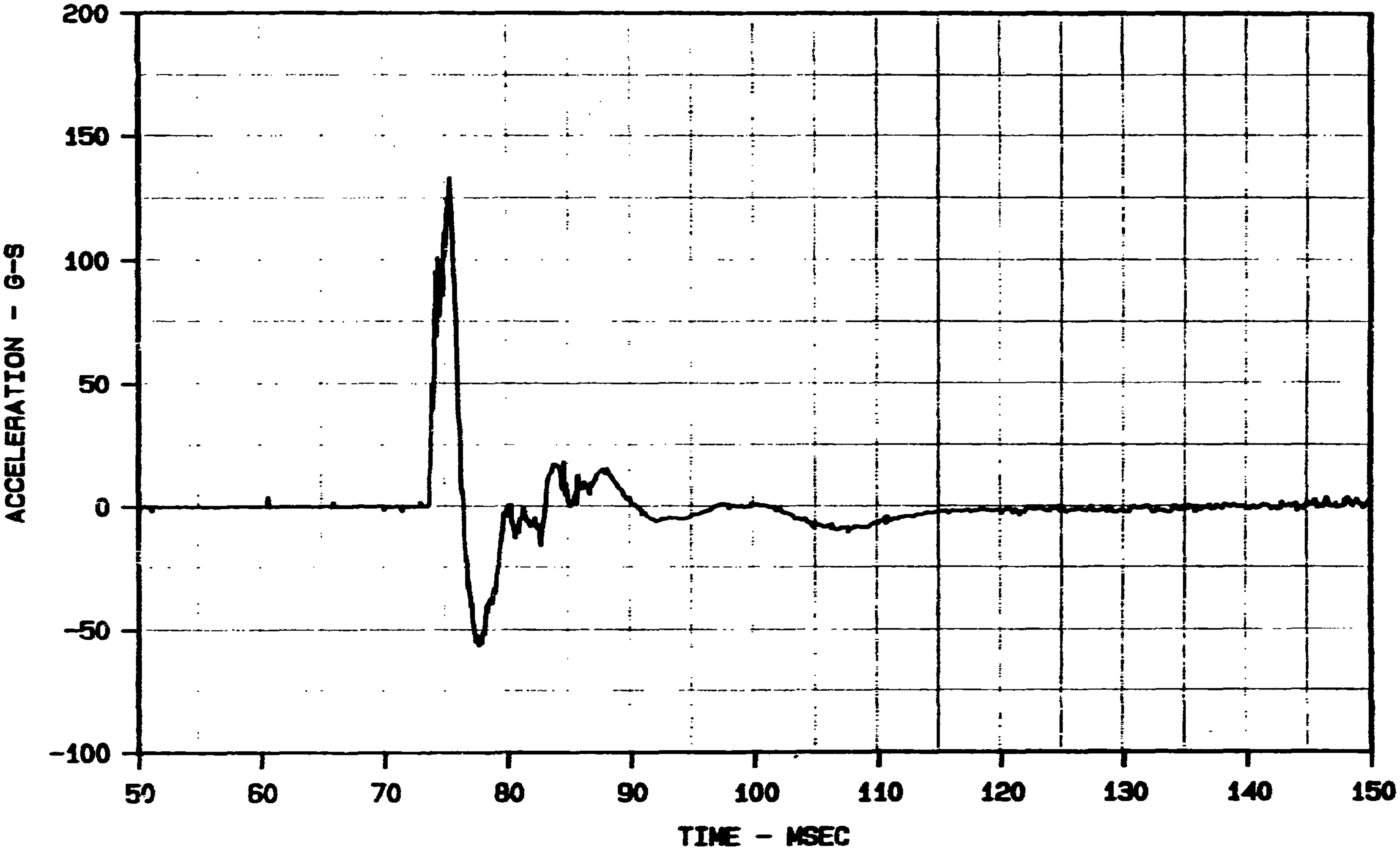


10
F2 LOW PASS 9500. HZ
CBS 50 150 0.58
NEW DEFLECTION 1670
MP A_4
EX 1635 NB-1
3109 106 106
125 KHZ 17-JUN-87
VELOCITY - FT/SEC
DISPL - FT
TIME - MSEC
5
4
3
2
1
0
-1
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
50
60
70
80
90
100
110
120
130
140
150

11 CBS 50 150 0.34 NEW DEFLECTION 1625

MP A_5

EX 1635 NB-1
3110 107 107
125 KHZ 17-JUN-87



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NEW DEFLECTION 1625

MP A_5

EX 1635 NB-1
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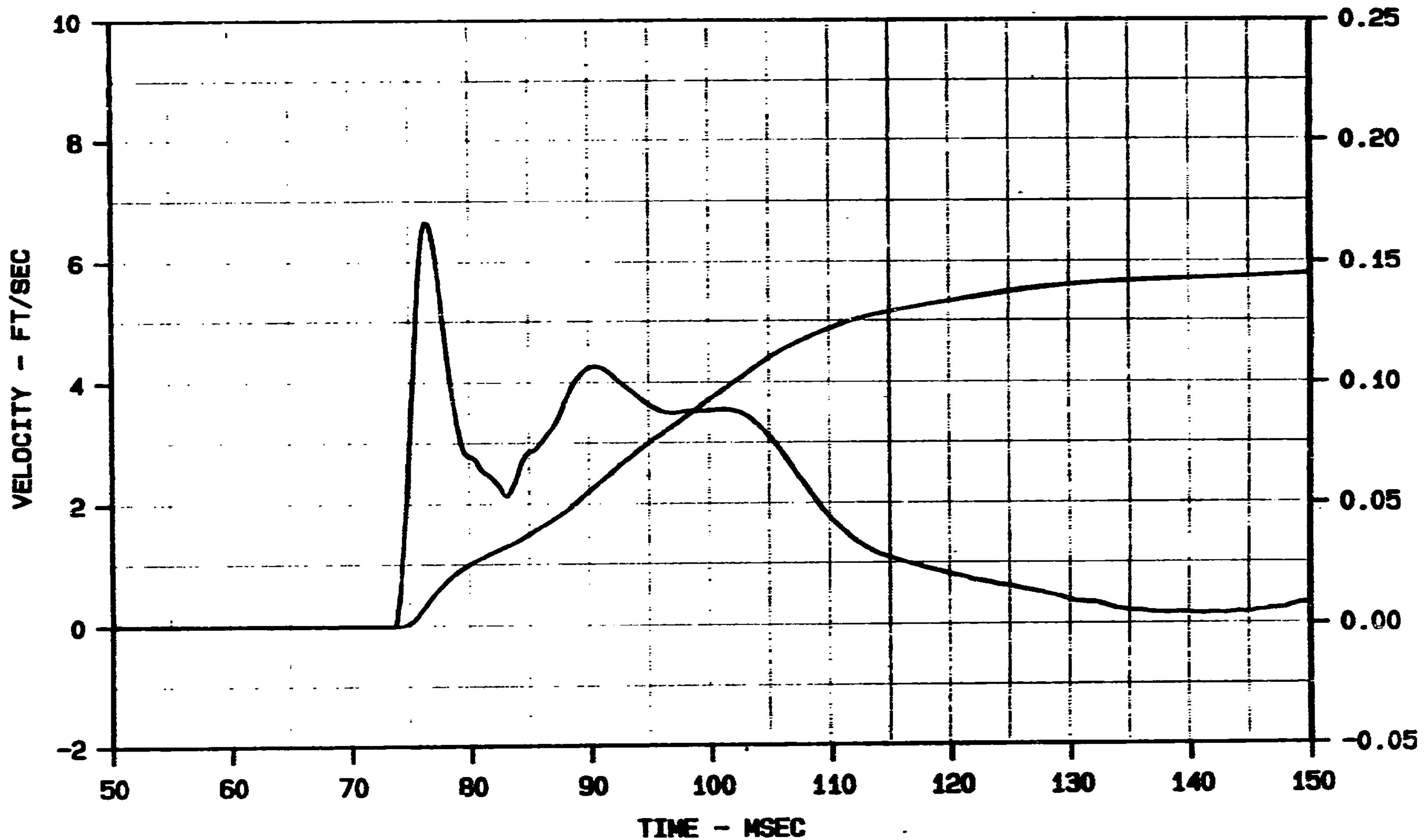
125 KHZ 17-JUN-87



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NEW DEFLECTION 1625

MP A_6

EX 1635 NB-1
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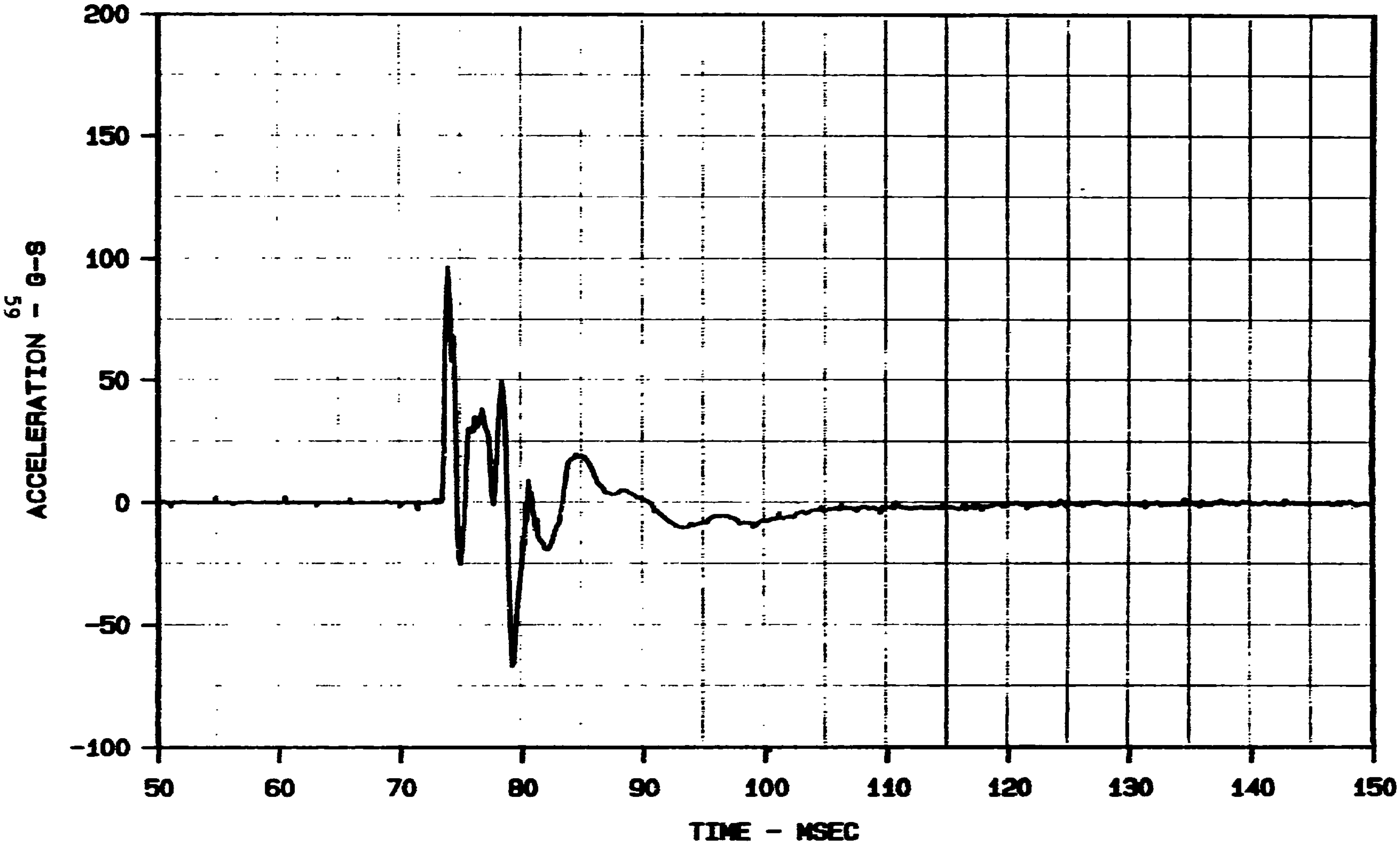
125 KHZ 17-JUN-87



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NEW DEFLECTION 1626

MP A_6

EX 1635 NB-1
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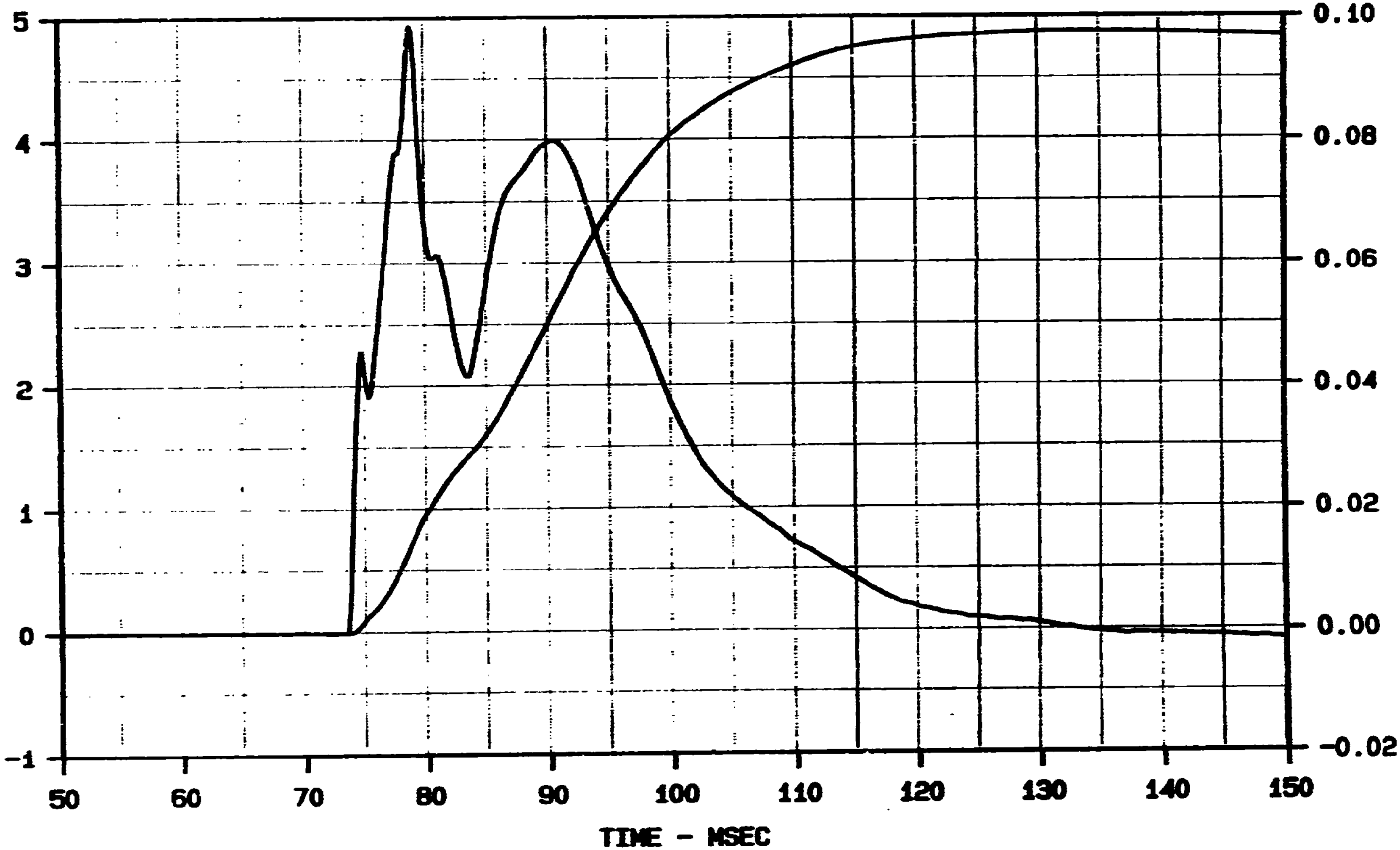

15 F2 LOW PASS 9800. HZ
CBS 80 150 0.82
NEW DEFLECTION 1825

MP A_7

EX 1635 NB-1
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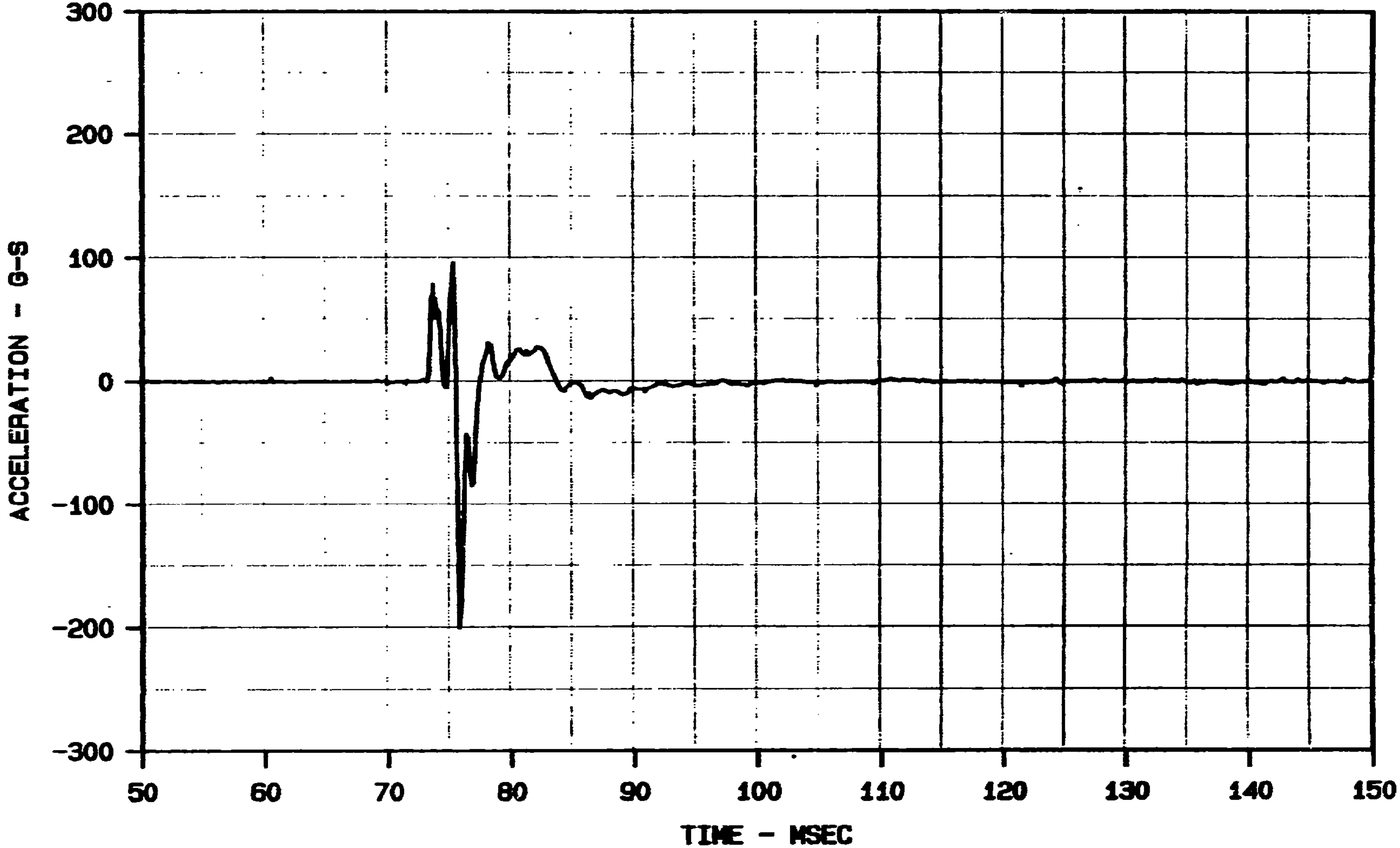
125 KHZ 17-JUN-87



16 F2 LOW PASS 9800. HZ
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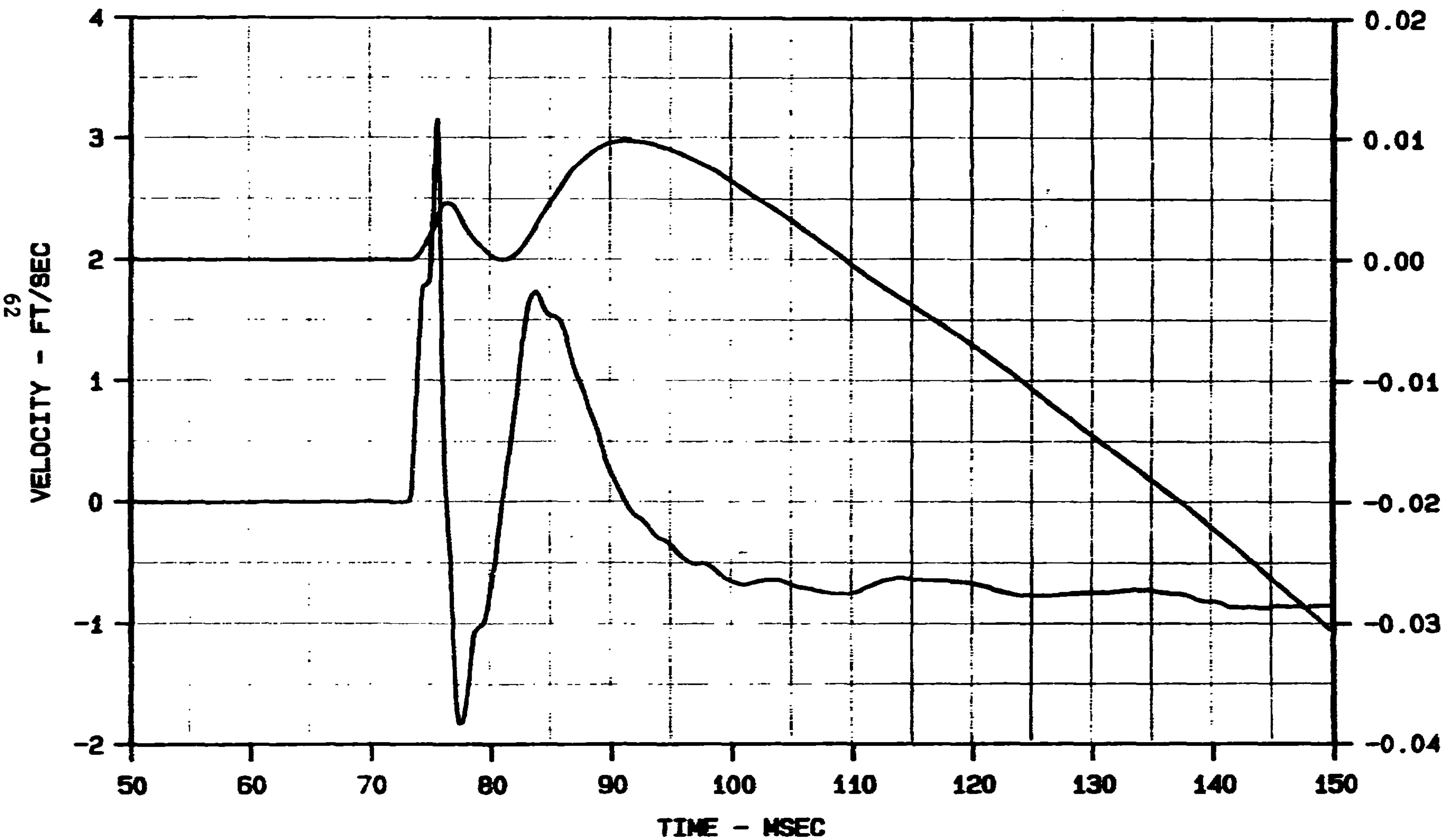
NEW DEFLECTION 1625

MP A_7

EX 1635 NB-1
3112 109 109
125 KHZ 17-JUN-87



17 CBS 50 150 0.63
NEW DEFLECTION 1640

MP A_B

EX 1635 NB-1
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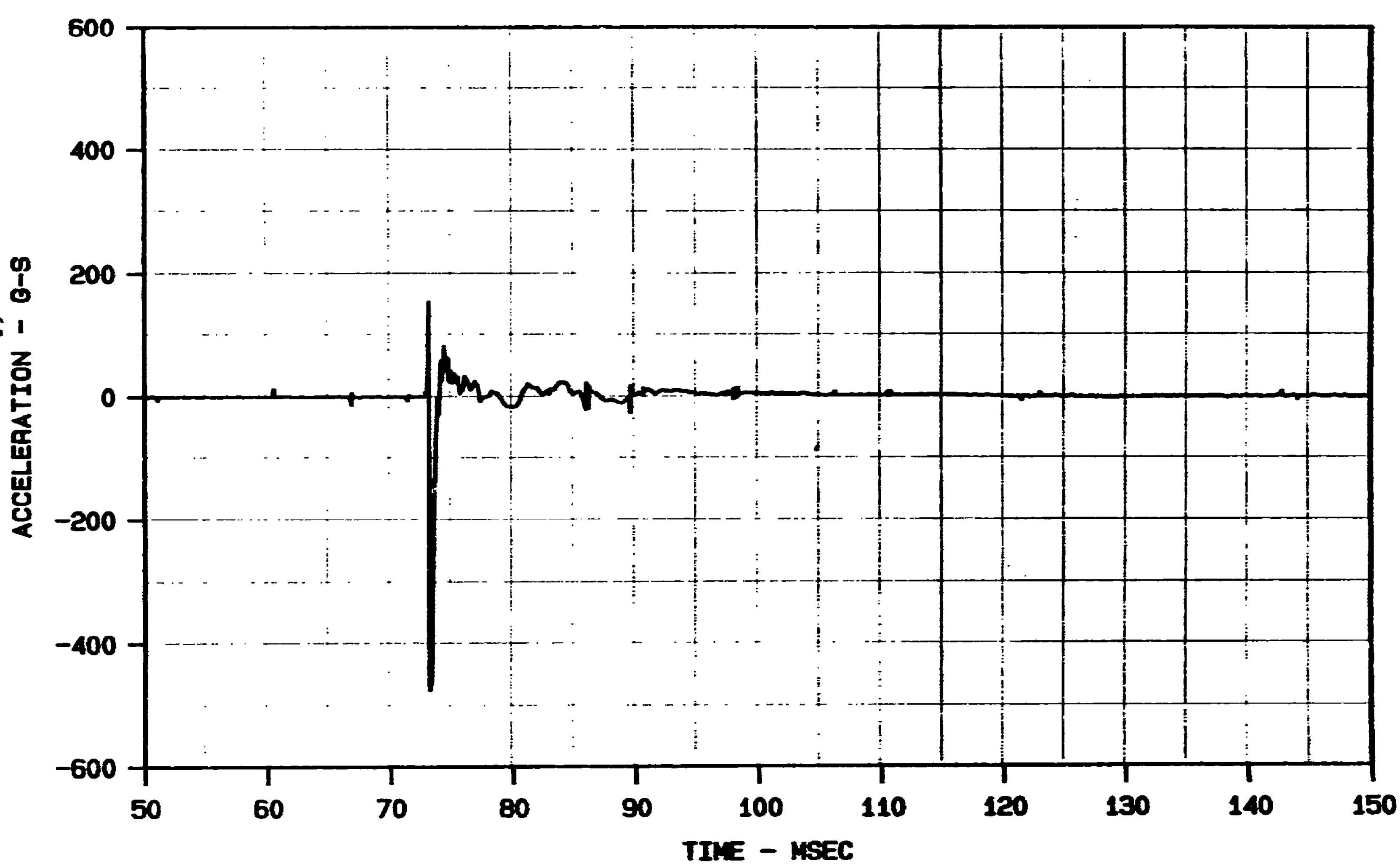
125 KHZ 17-JUN-87



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NEW DEFLECTION 1640

MP A_B

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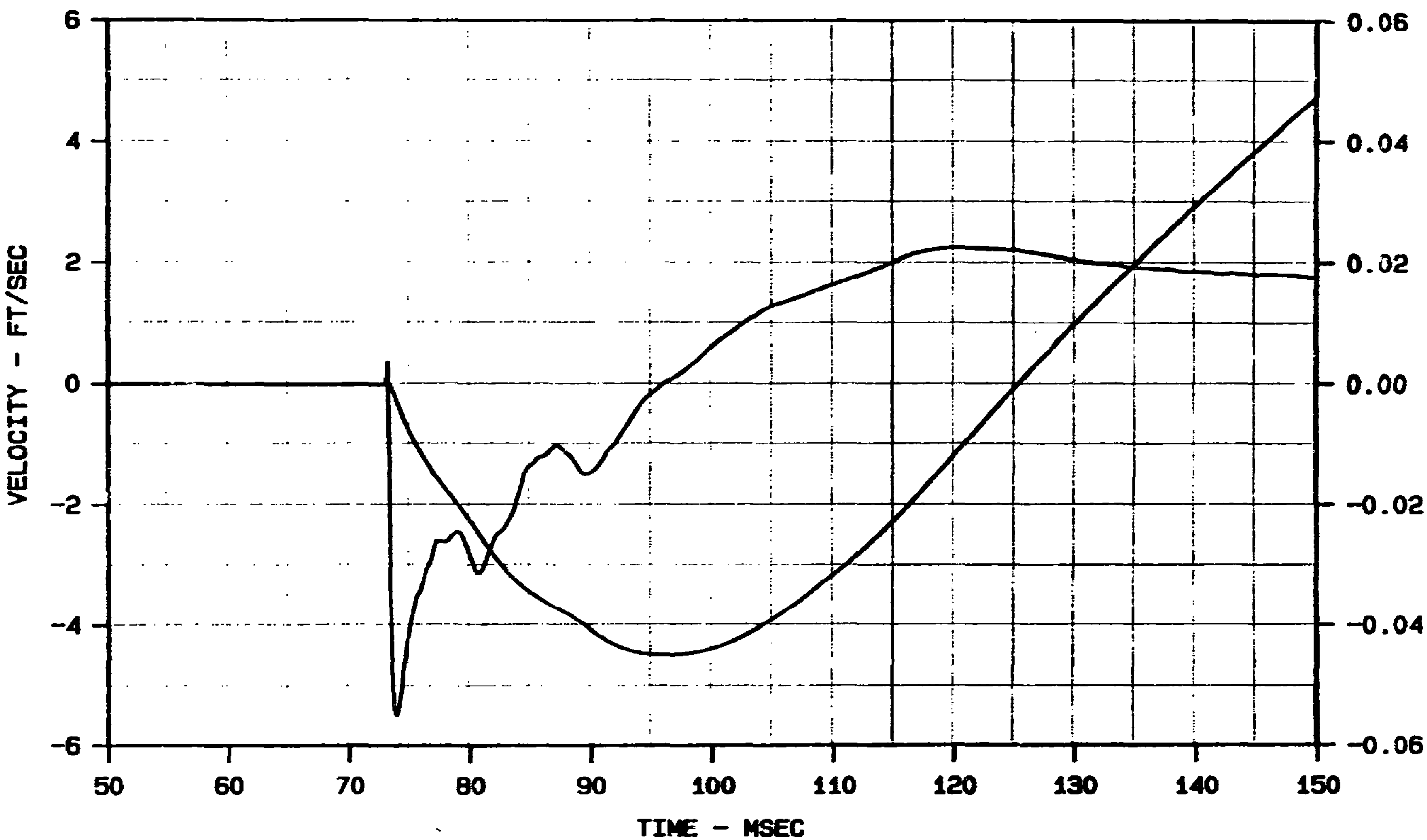

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MIN DEFLECTION 1630

MP A_9

EX 1635 NB-1
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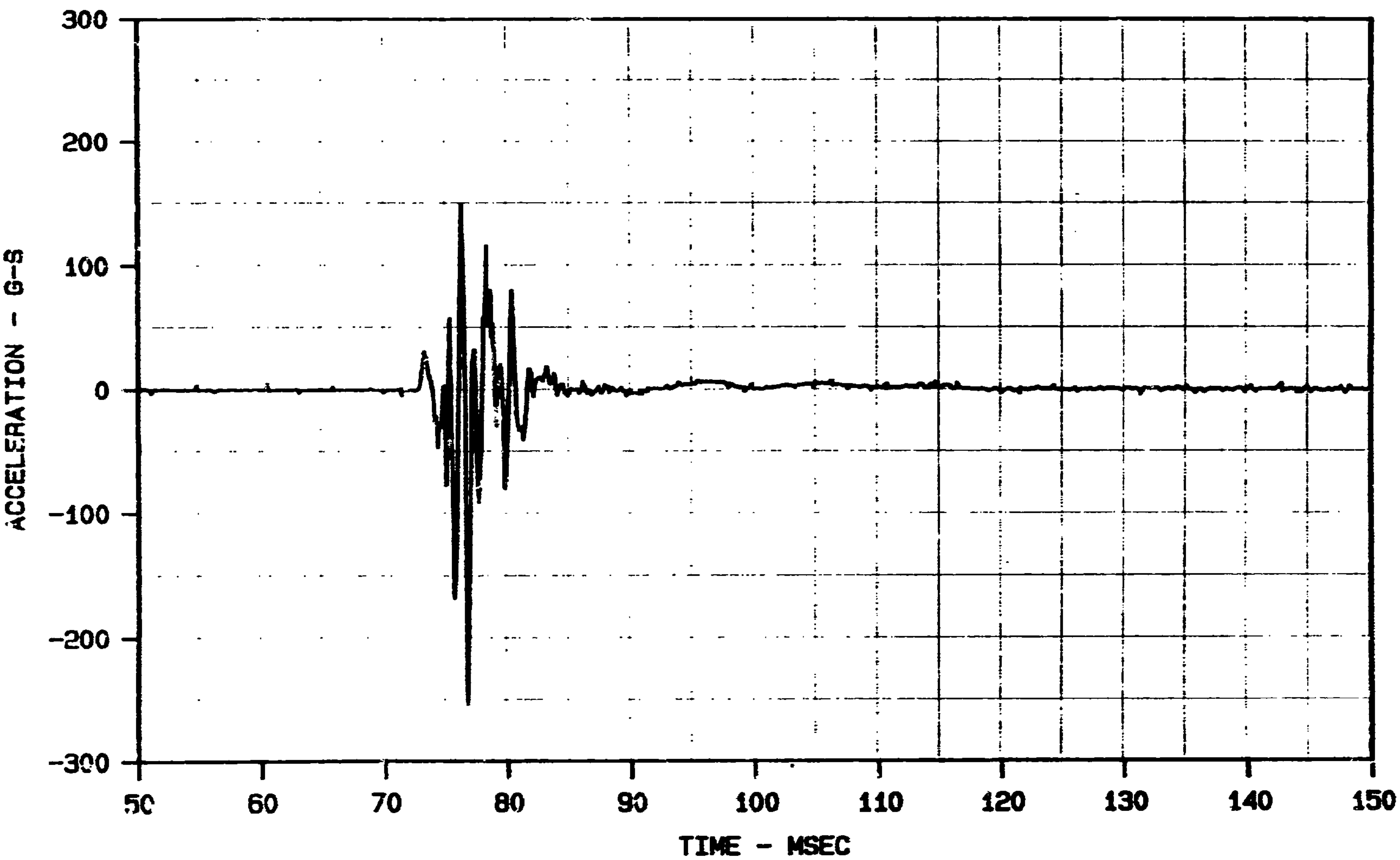
125 KHZ 17-JUN-87



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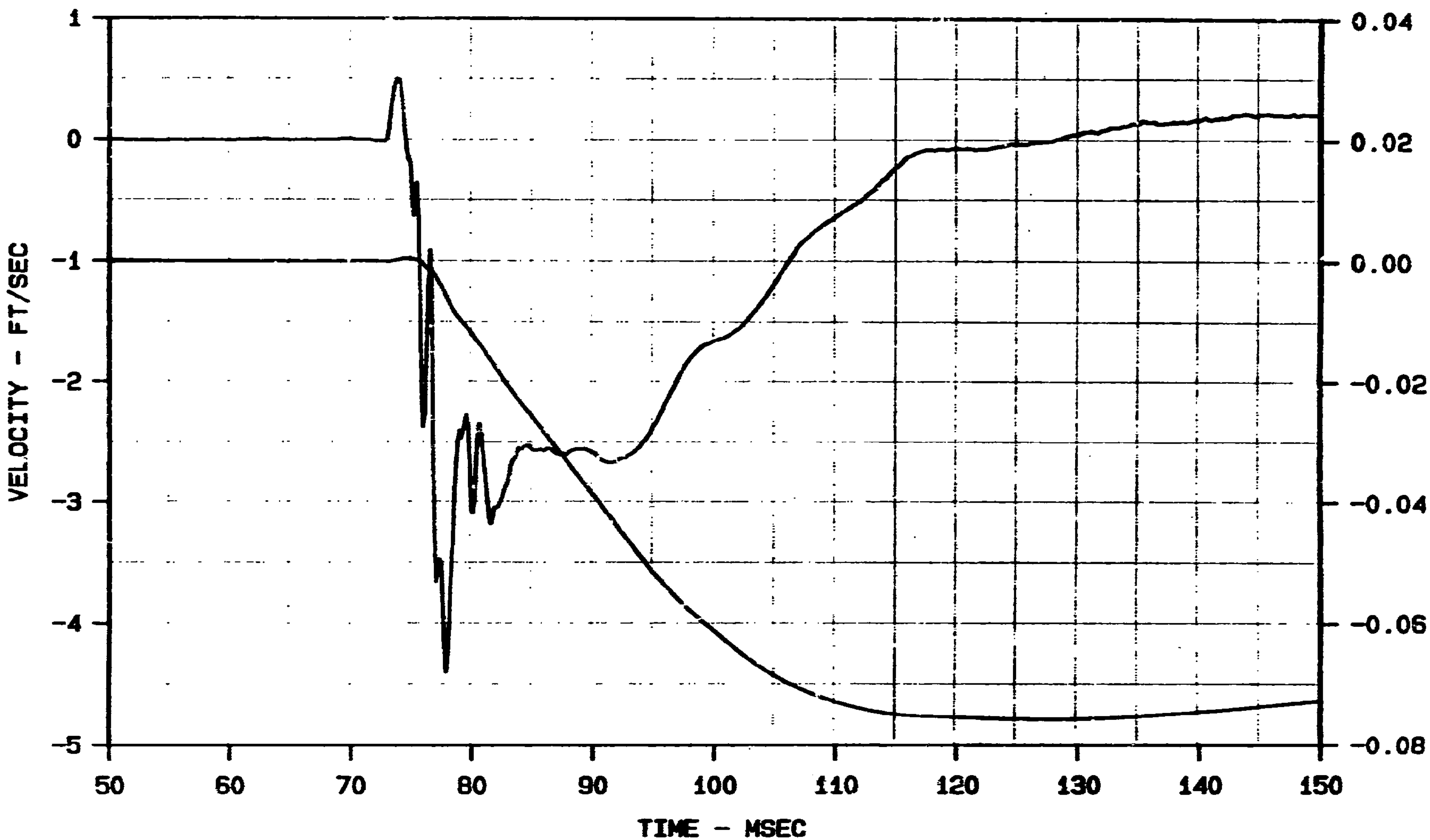
CBS 50 15? 0.600
NEW DEFLECTION 1630

MP A_9

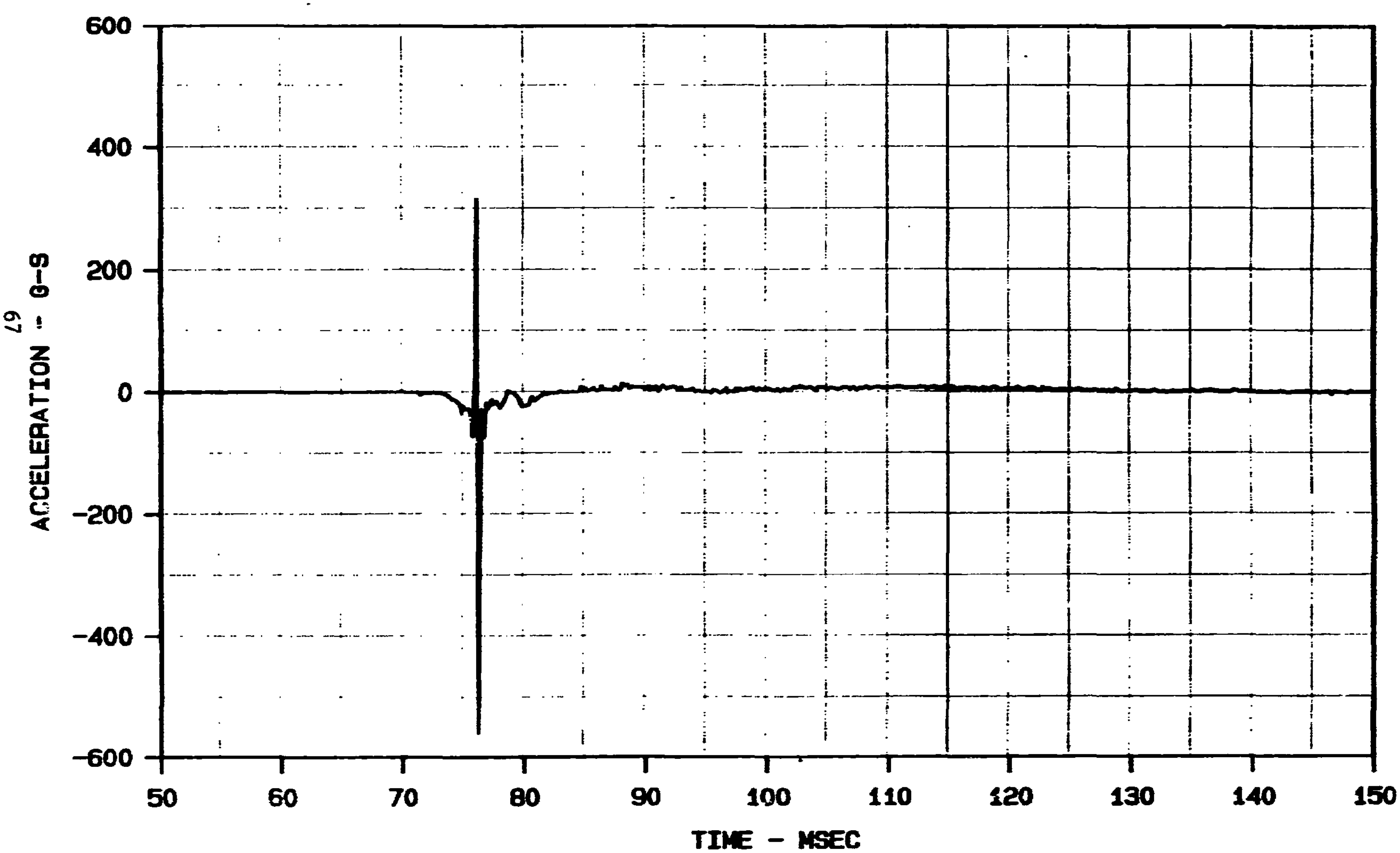
EX 1635 NB-1
3114 111 111
125 KHZ 17-JUN-87

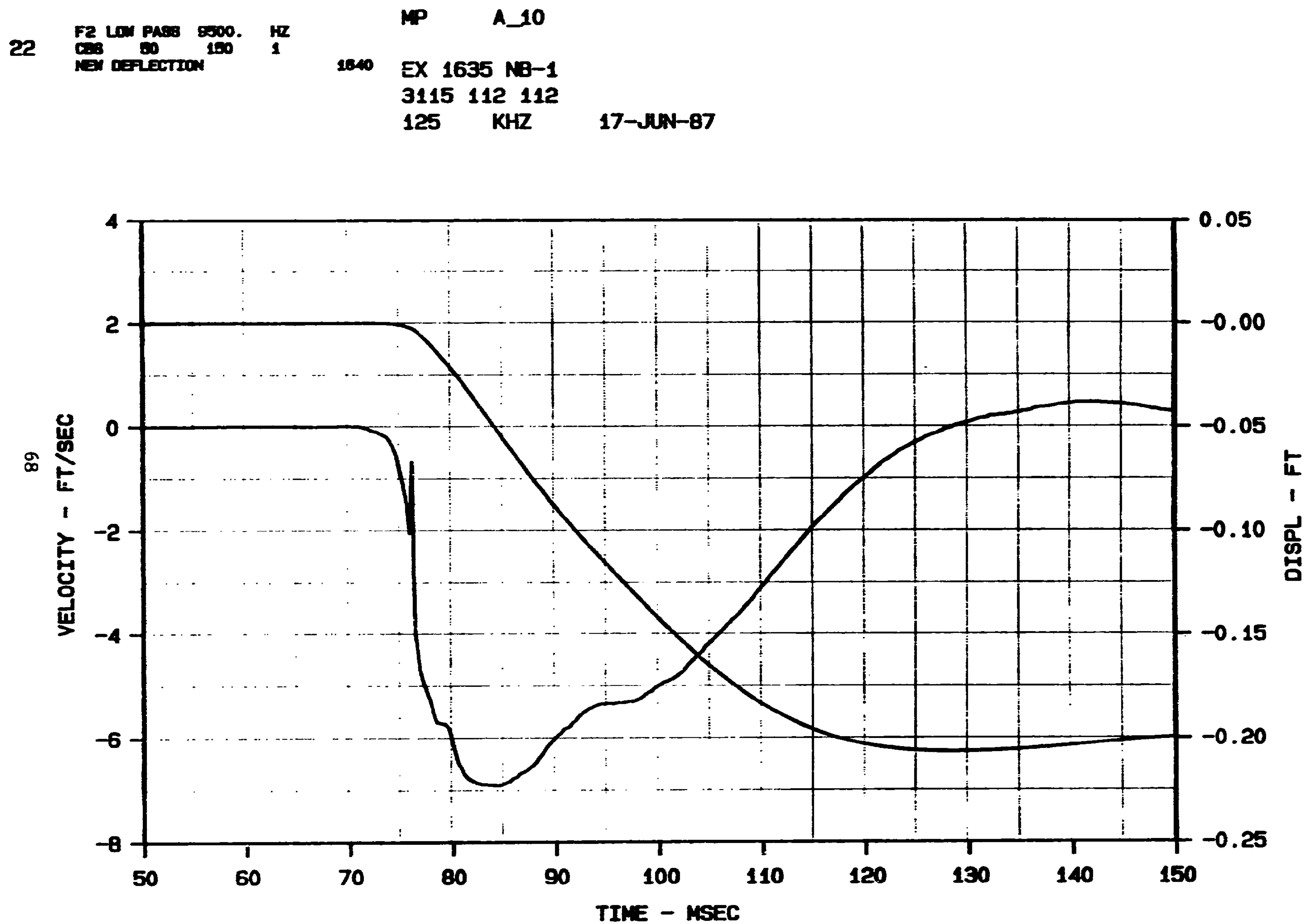


21 F2 LOW PASS 9800. HZ
CBS SC 150 1
NEW DEFLECTION 1640

MP A_10

EX 1635 NB-1
3115 112 112
125 KHZ 17-JUN-87

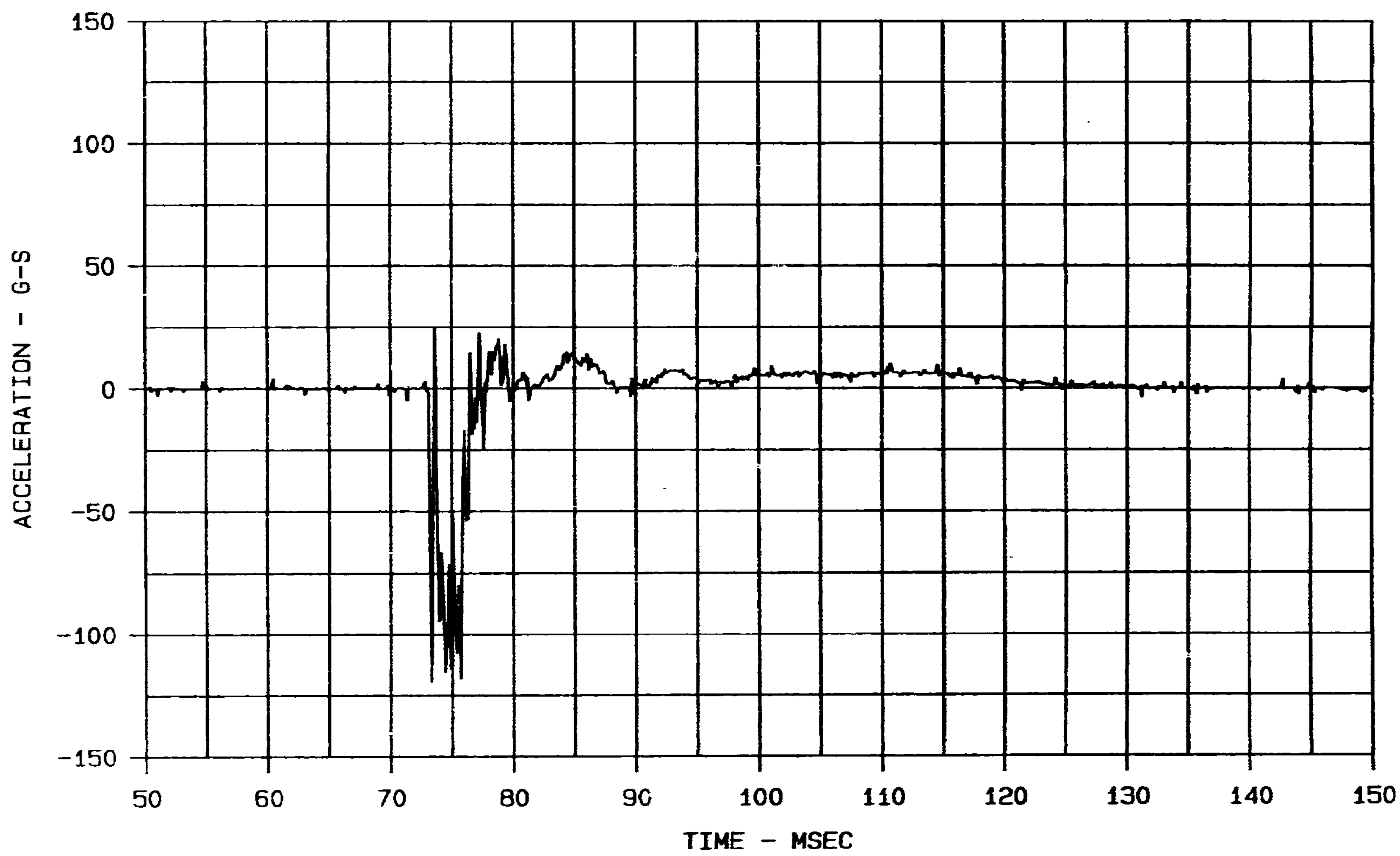



22
F2 LOW PASS 9500. HZ
CBS 50 150 1
NEW DEFLECTION 1640
MP A_10
EX 1635 NB-1
3115 112 112
125 KHZ 17-JUN-87
VELOCITY - FT/SEC
4
2
0
-2
-4
-6
-8
DISPL - FT
0.05
-0.00
-0.05
-0.10
-0.15
-0.20
-0.25
50
60
70
80
90
100
110
120
130
140
150
TIME - MSEC

3 F2 LOW PASS 9500. HZ
CBS 50 150 1.1
NEW DEFLECTION 1635

MP A_11

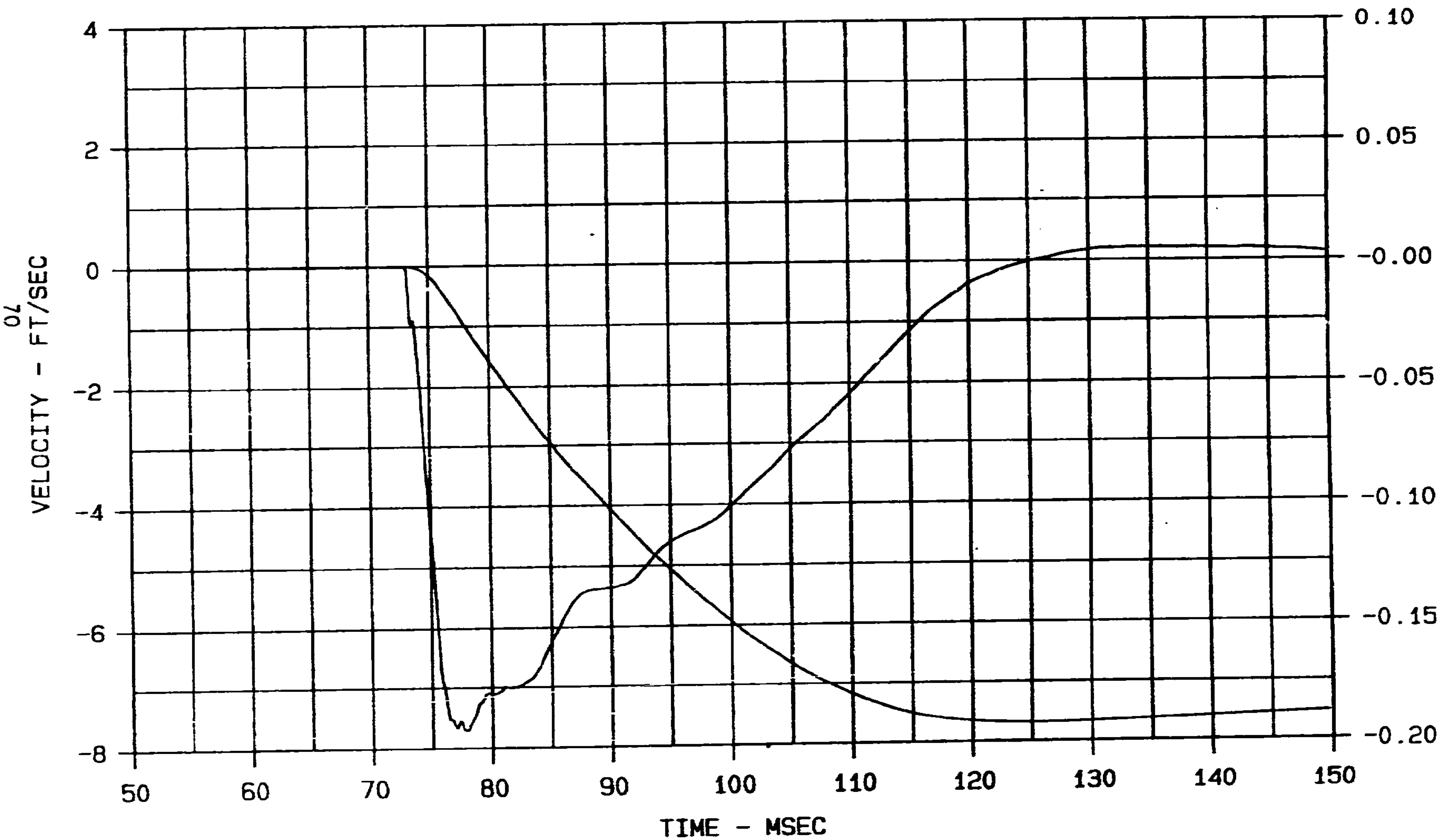
EX 1635 NB-1
3116 113 113
125 KHZ 25-JUN-87



4 F2 LOW PASS 9500. HZ
CBS 50 150 1.1
NEW DEFLECTION 1635

MP A_11

EX 1635 NB-1
3116 113 113
125 KHZ 25-JUN-87

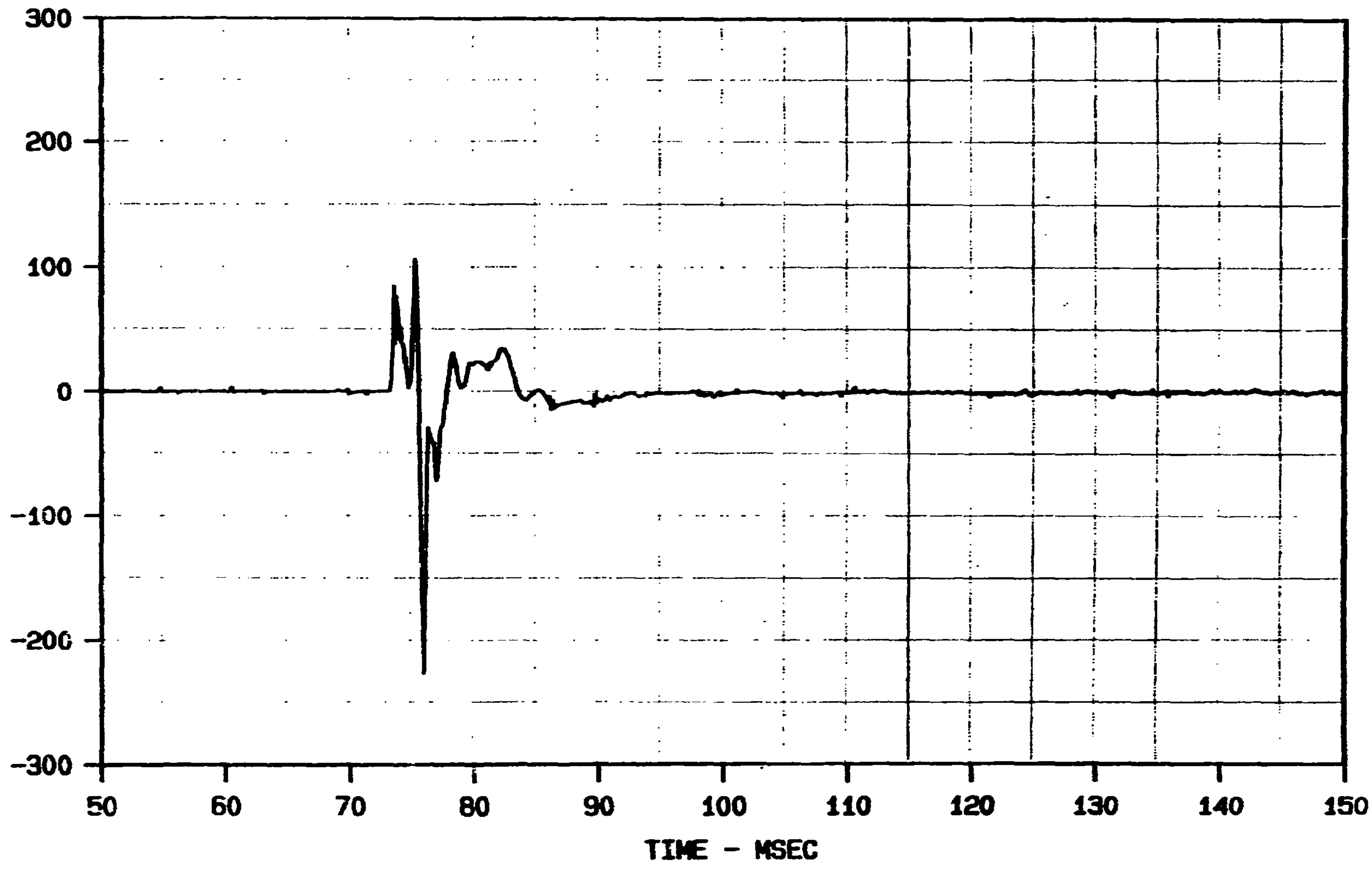


25

F2 LOW PASS 9500. HZ
CBS 50 150 0.42
NEW DEFLECTION 1540

MP A_12

EX 1635 NB-1
3117 114 114
125 KHZ 17-JUN-87

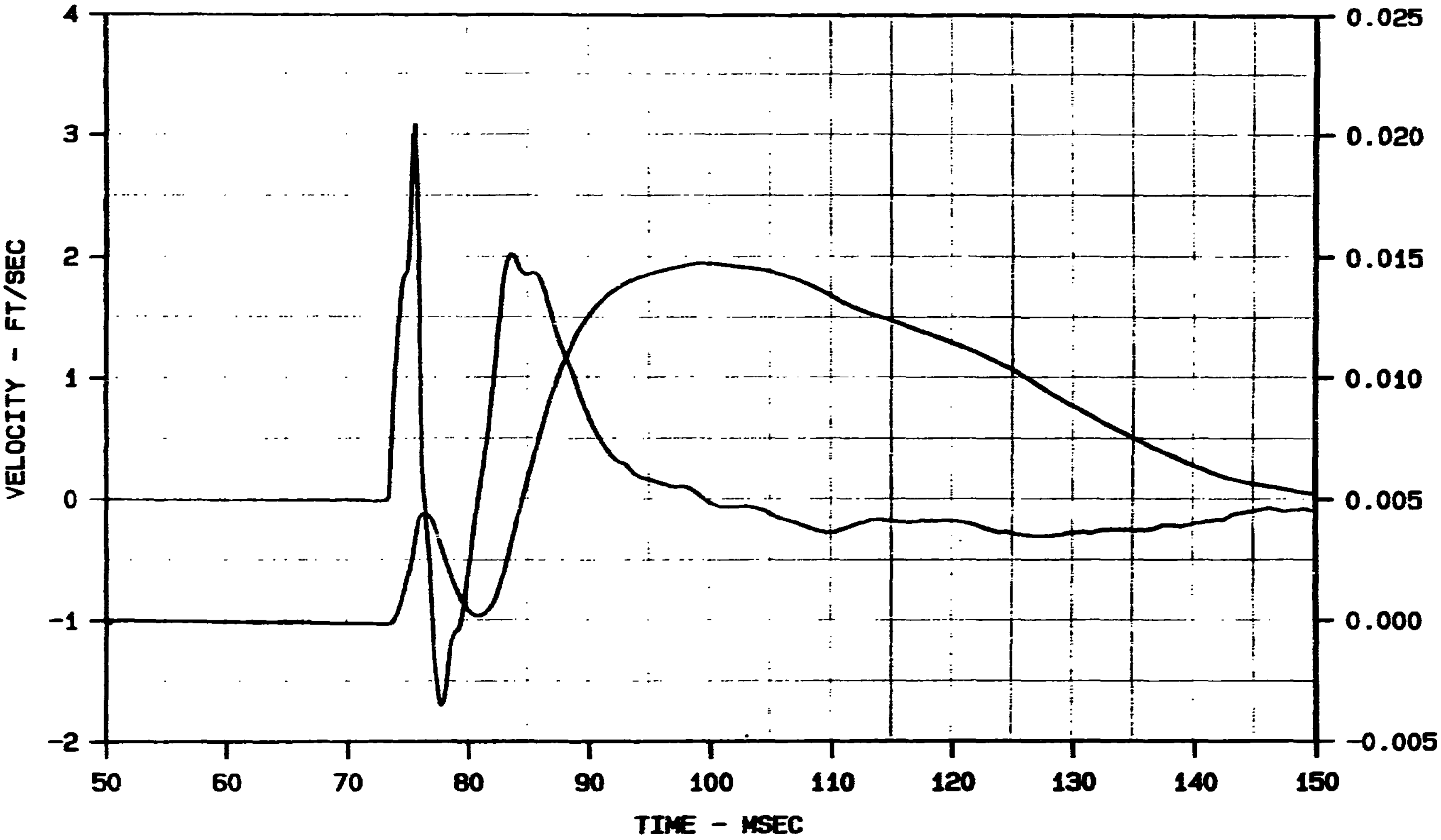


26

F2 LOW PASS 9500. HZ
CBS 50 150 0.42
NEW DEFLECTION 1640

MP A_12

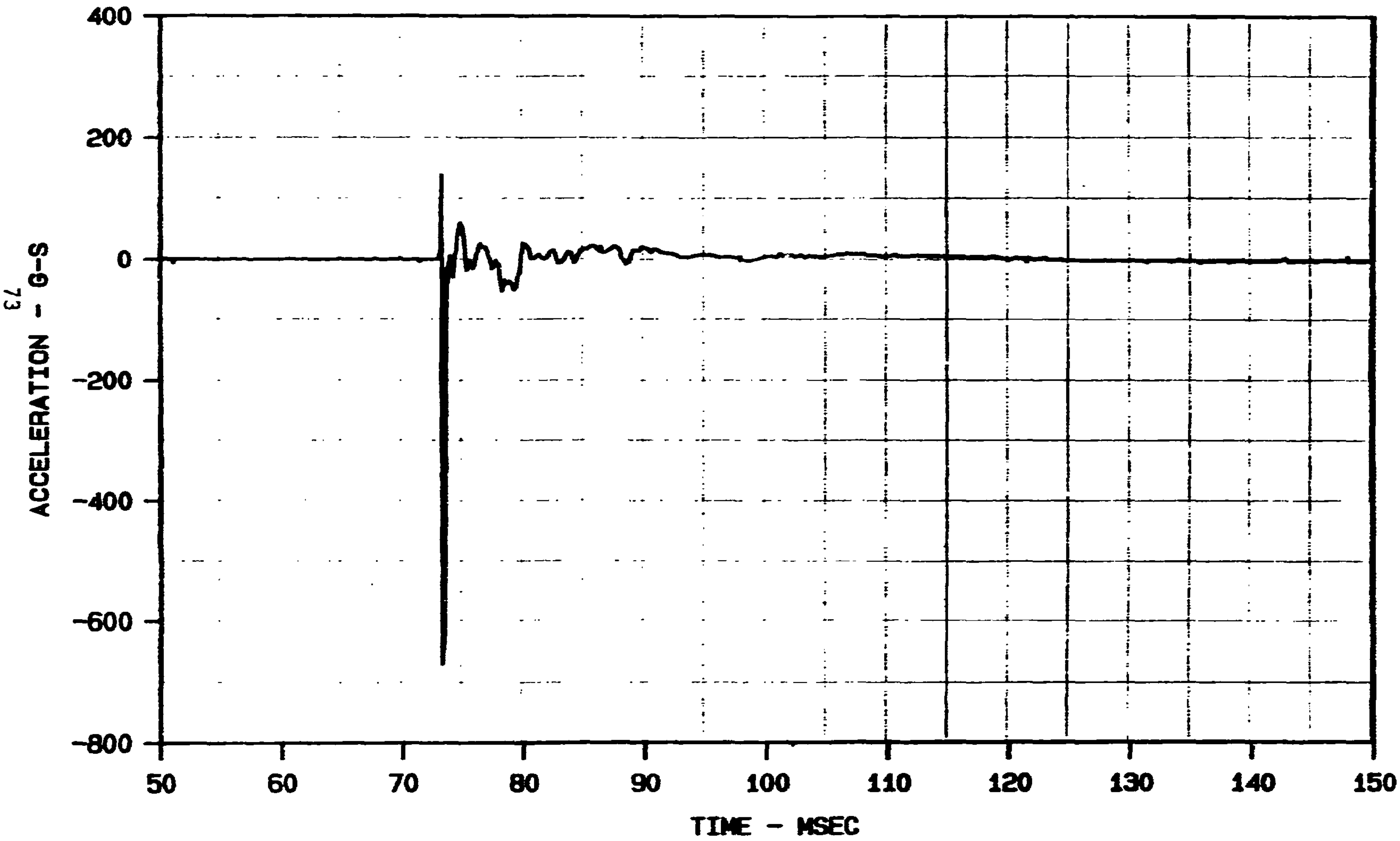
EX 1635 NB-1
3117 114 114
125 KHZ 17-JUN-87



27 F2 LOW PASS 9500. HZ
CBB 50 150 0.8
NEW DEFLECTION 1645

MP A_13

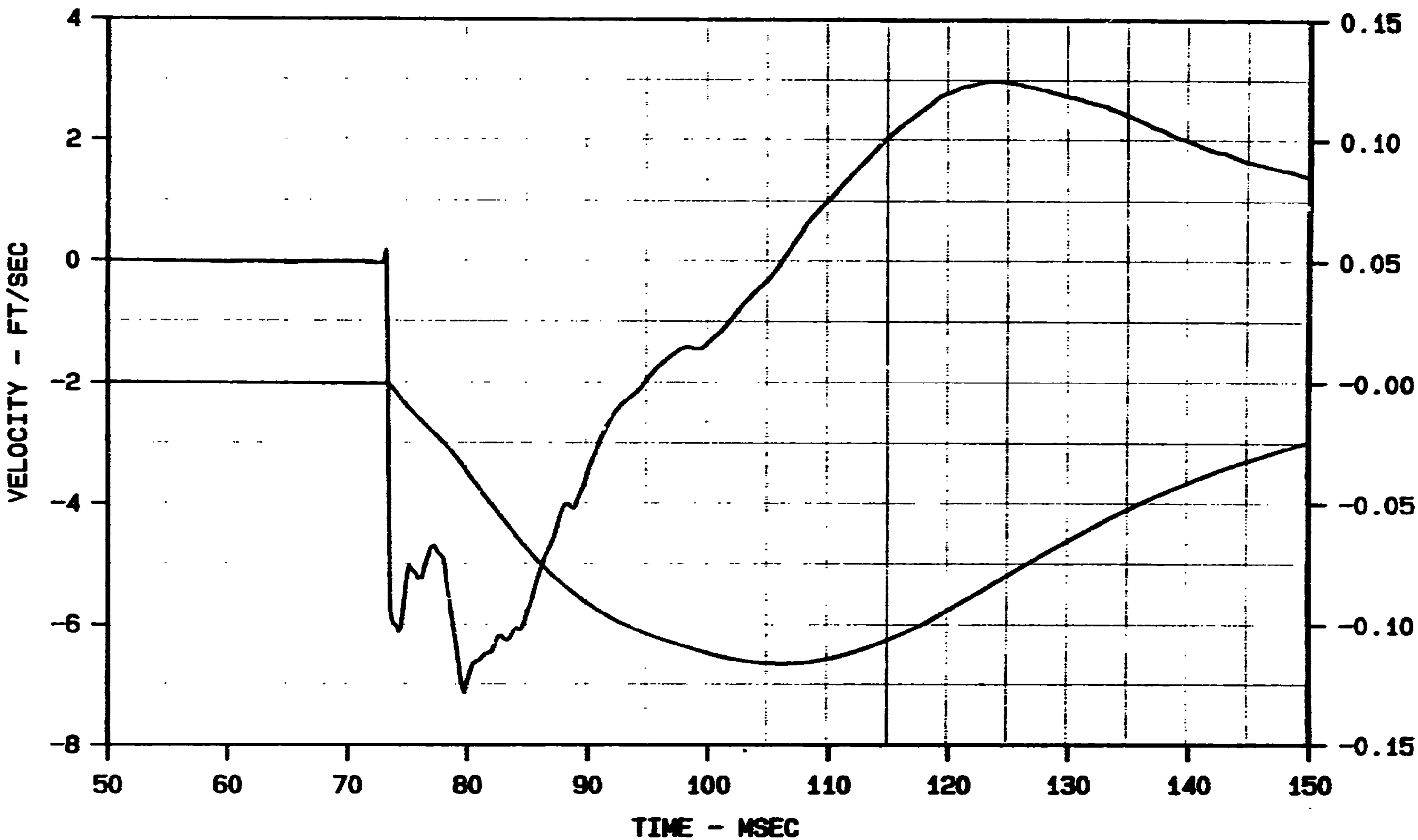
EX 1635 NB-1
3118 115 115
125 KHZ 17-JUN-87



28 F2 LOW PASS 9500. HZ
CBS 50 150 0.8
NEW DEFLECTION 1645

MP A_13

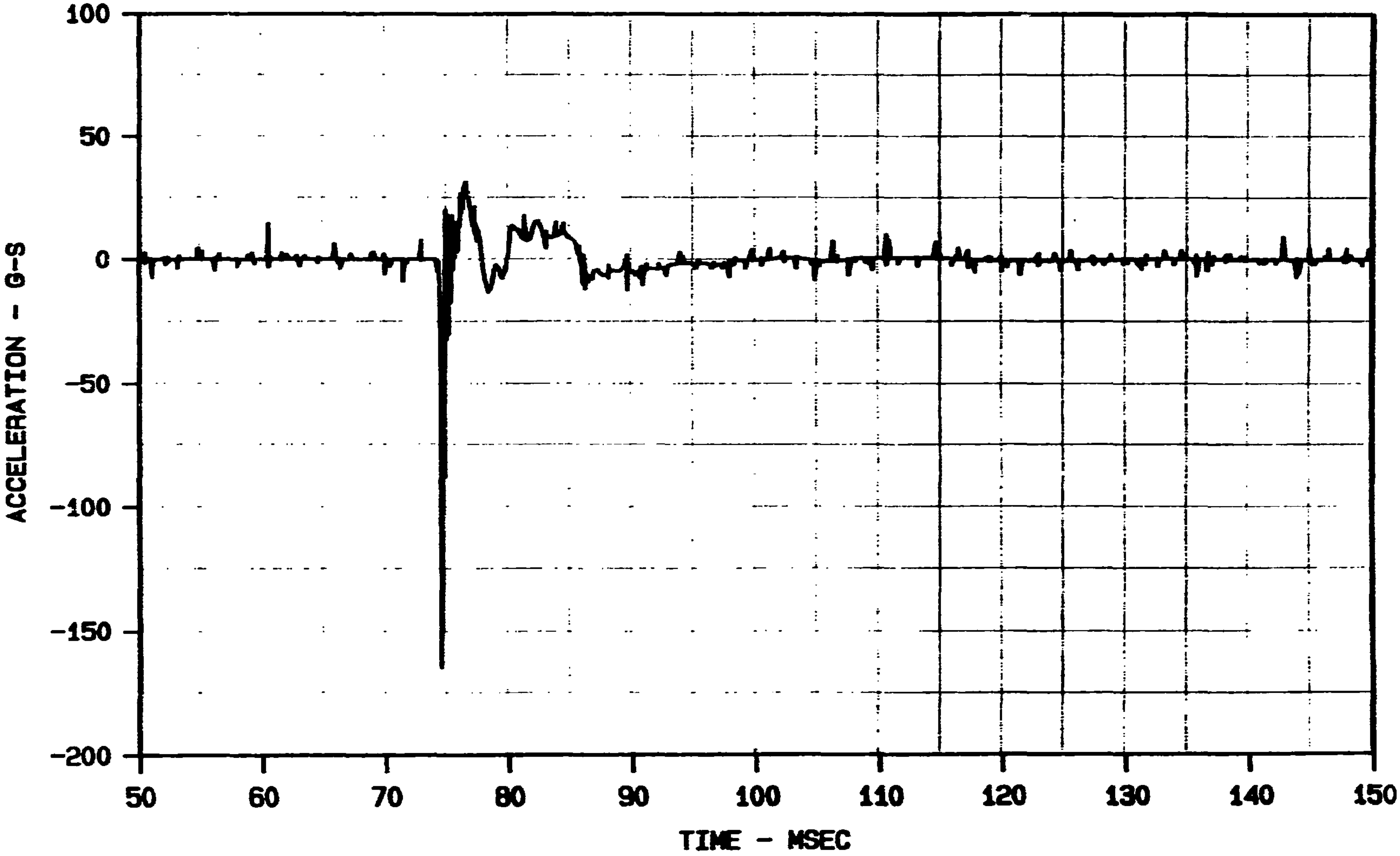
EX 1635 NB-1
3118 115 115
125 KHZ 17-JUN-87



29 CBS 50 150 0.31
NEW DEFLECTION 1782

MP AFF_1H

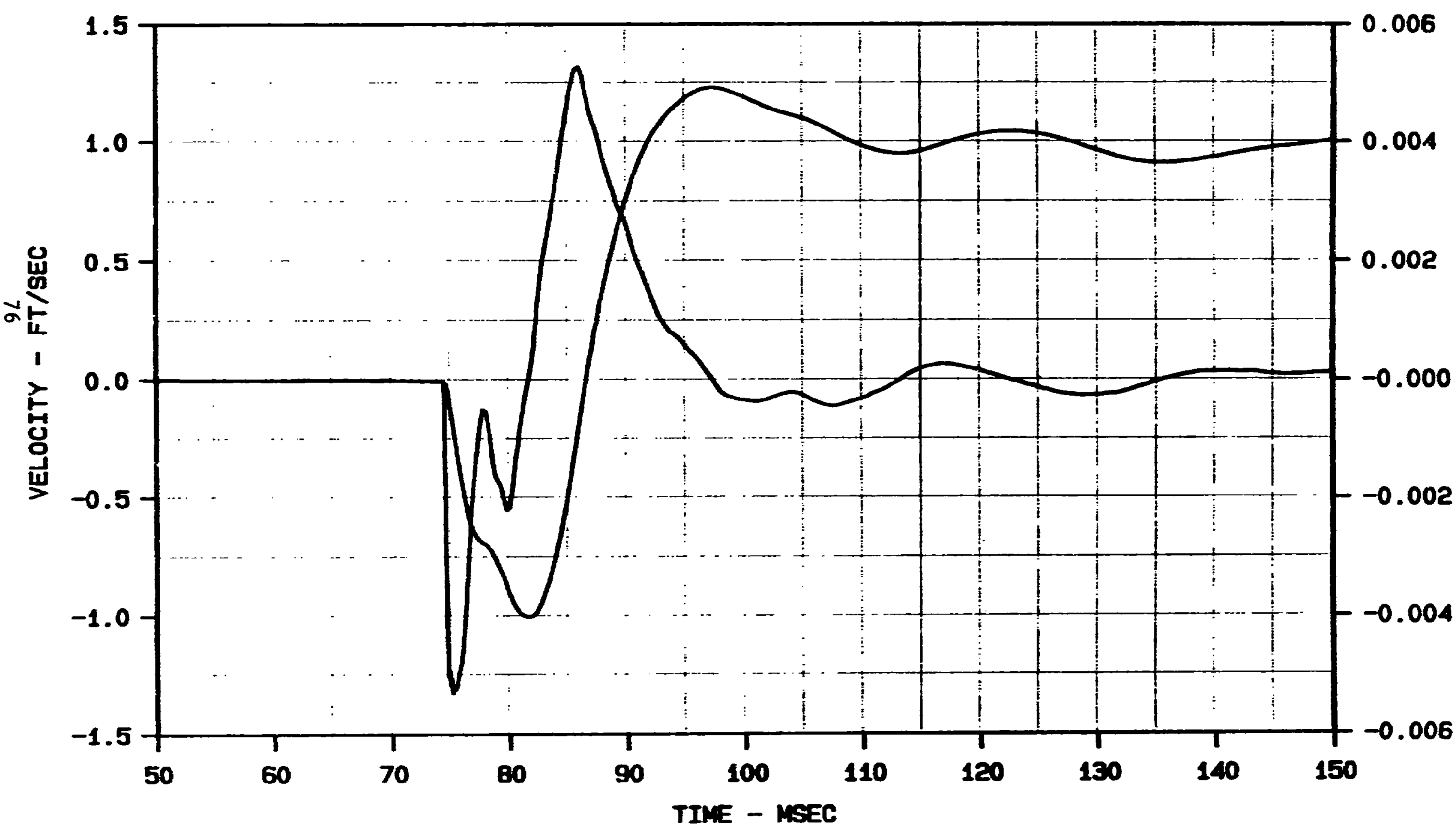
EX 1635 NB-1
3119 116 116
125 KHZ 17-JUN-87



30 CBS 50 100 0.31 NEW DEFLECTION 1782

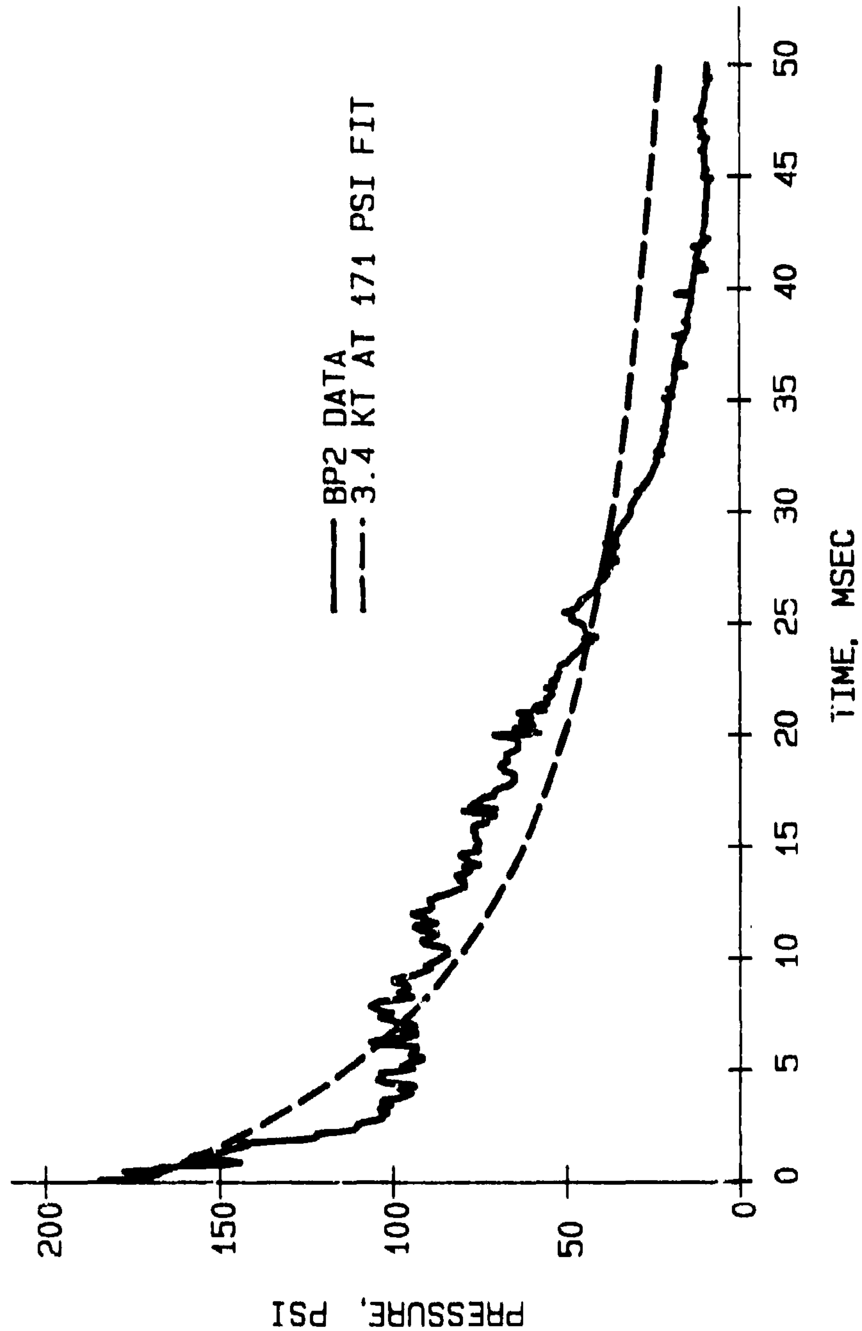
MP AFF_1H

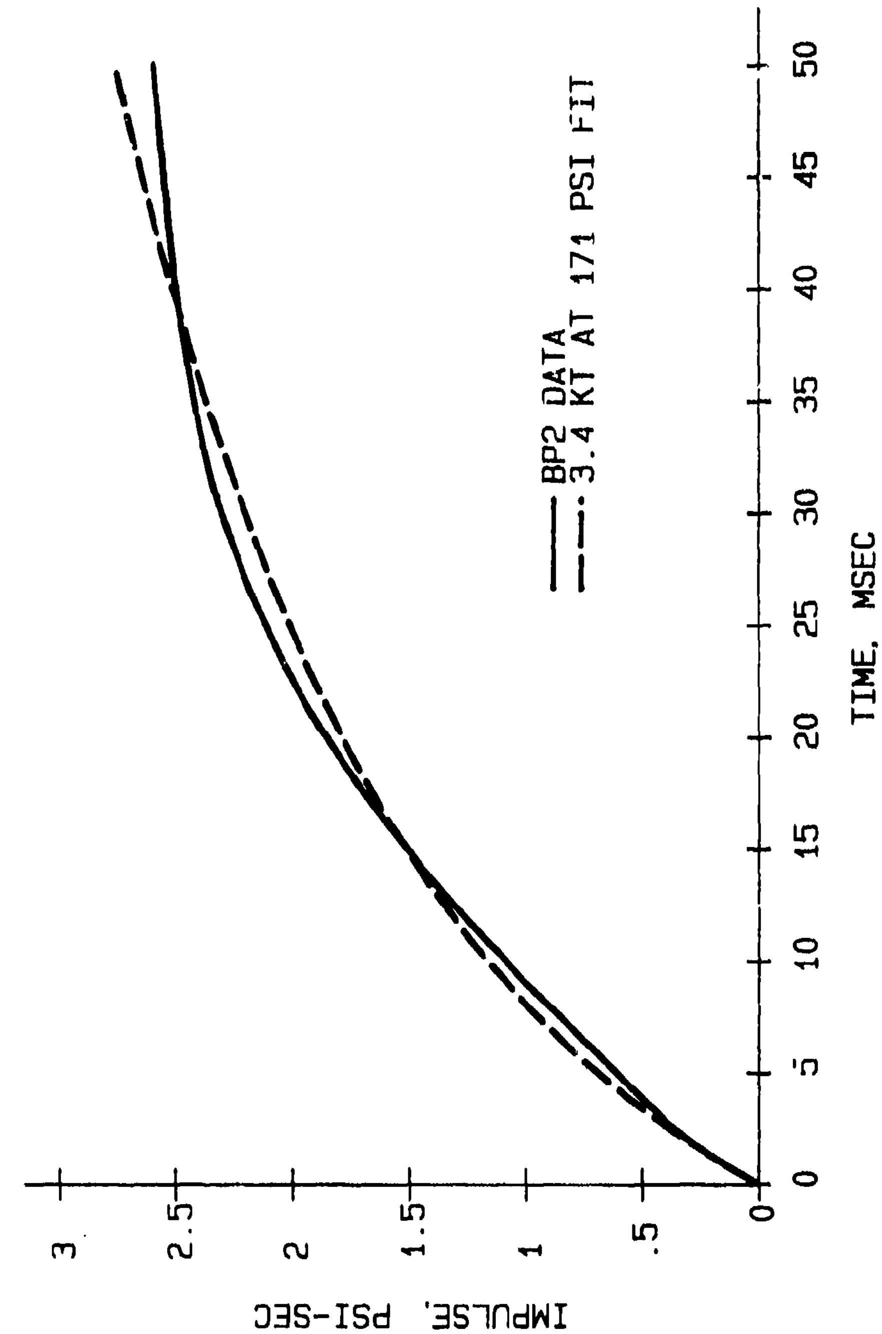
EX 1635 NB-1
3119 116 116
125 KHZ 17-JUN-87



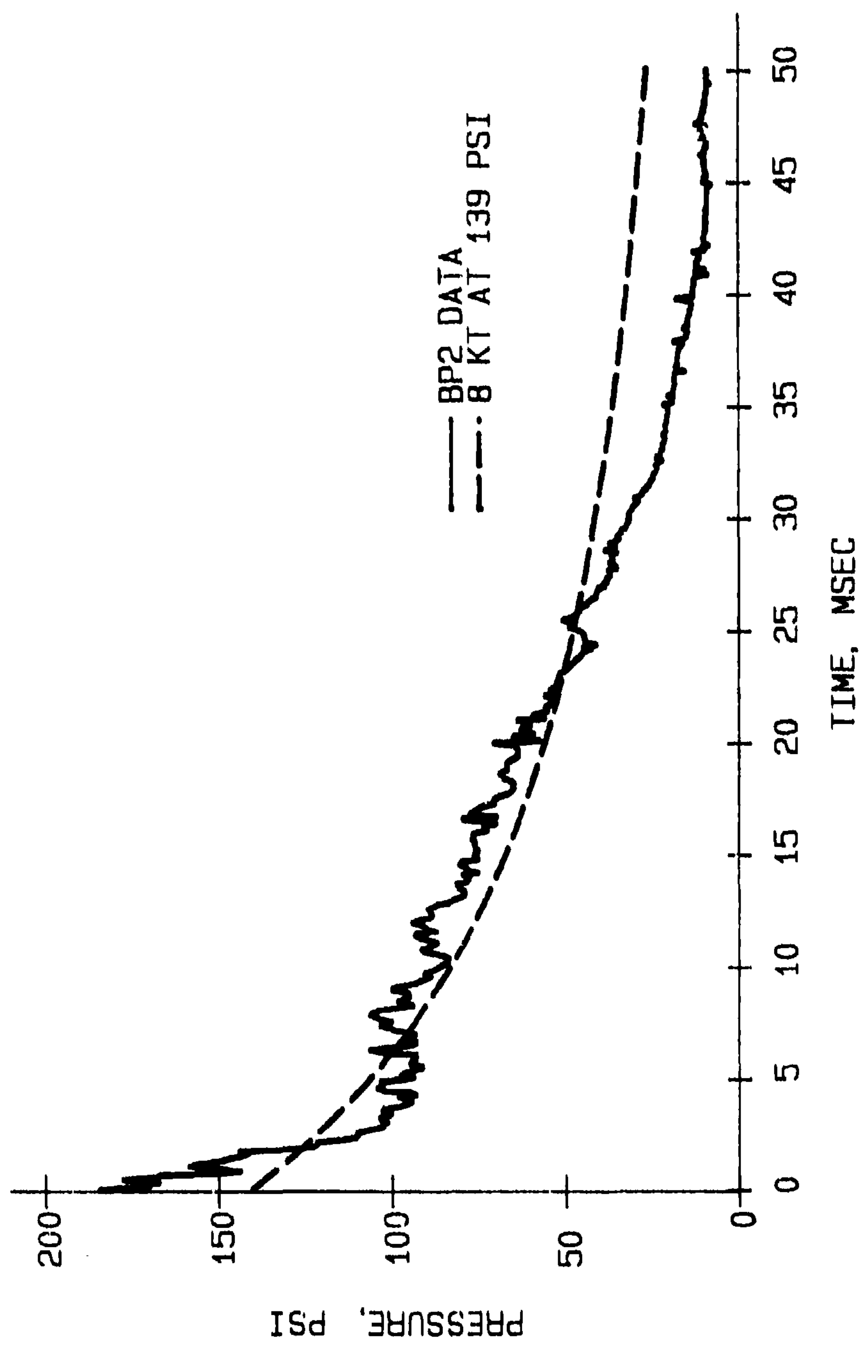
APPENDIX C

NUCLEAR WEAPON SIMULATIONS

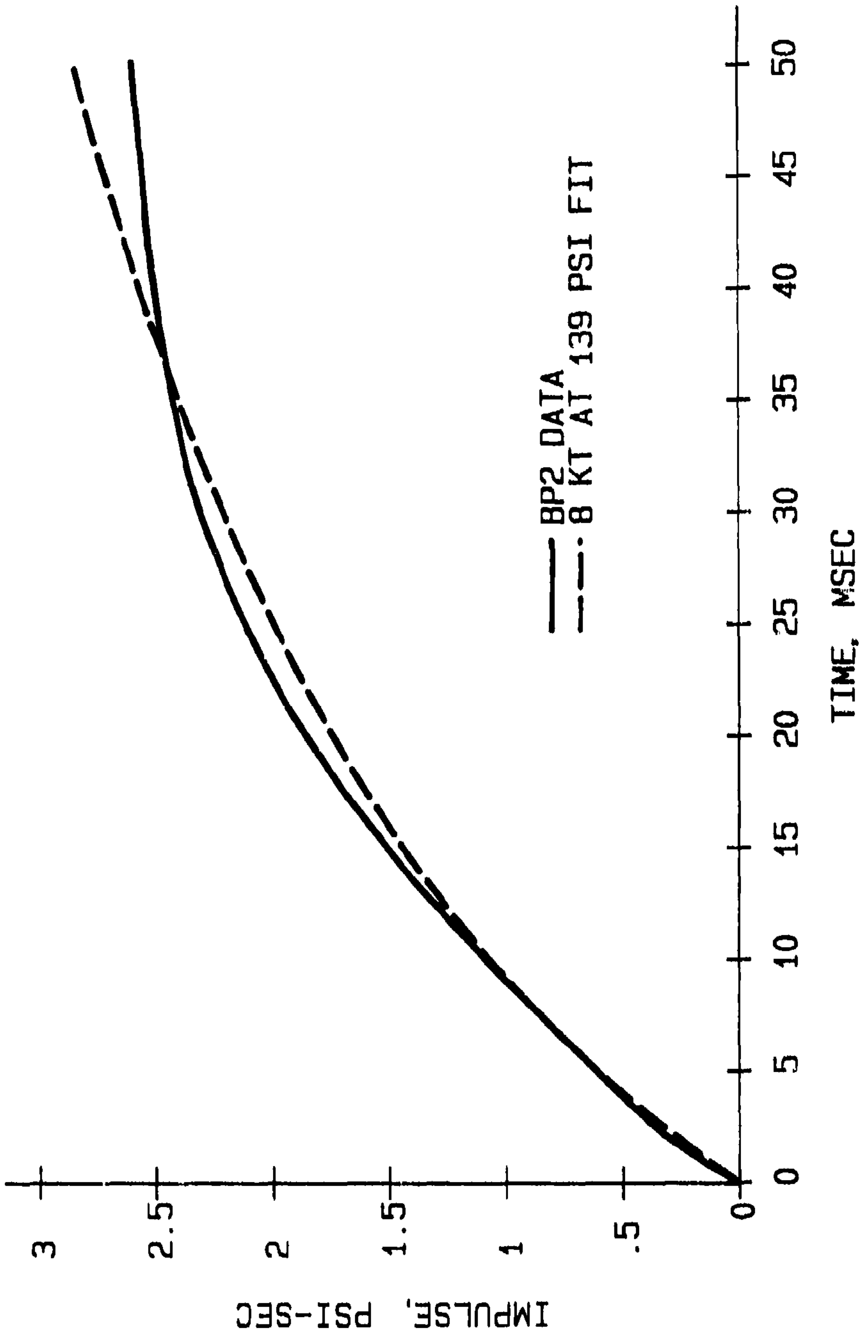

BP2 DATA
3.4 KT AT 171 PSI FIT
PRESSURE, PSI
0
50
100
150
200
TIME, MSEC
0
5
10
15
20
25
30
35
40
45
50

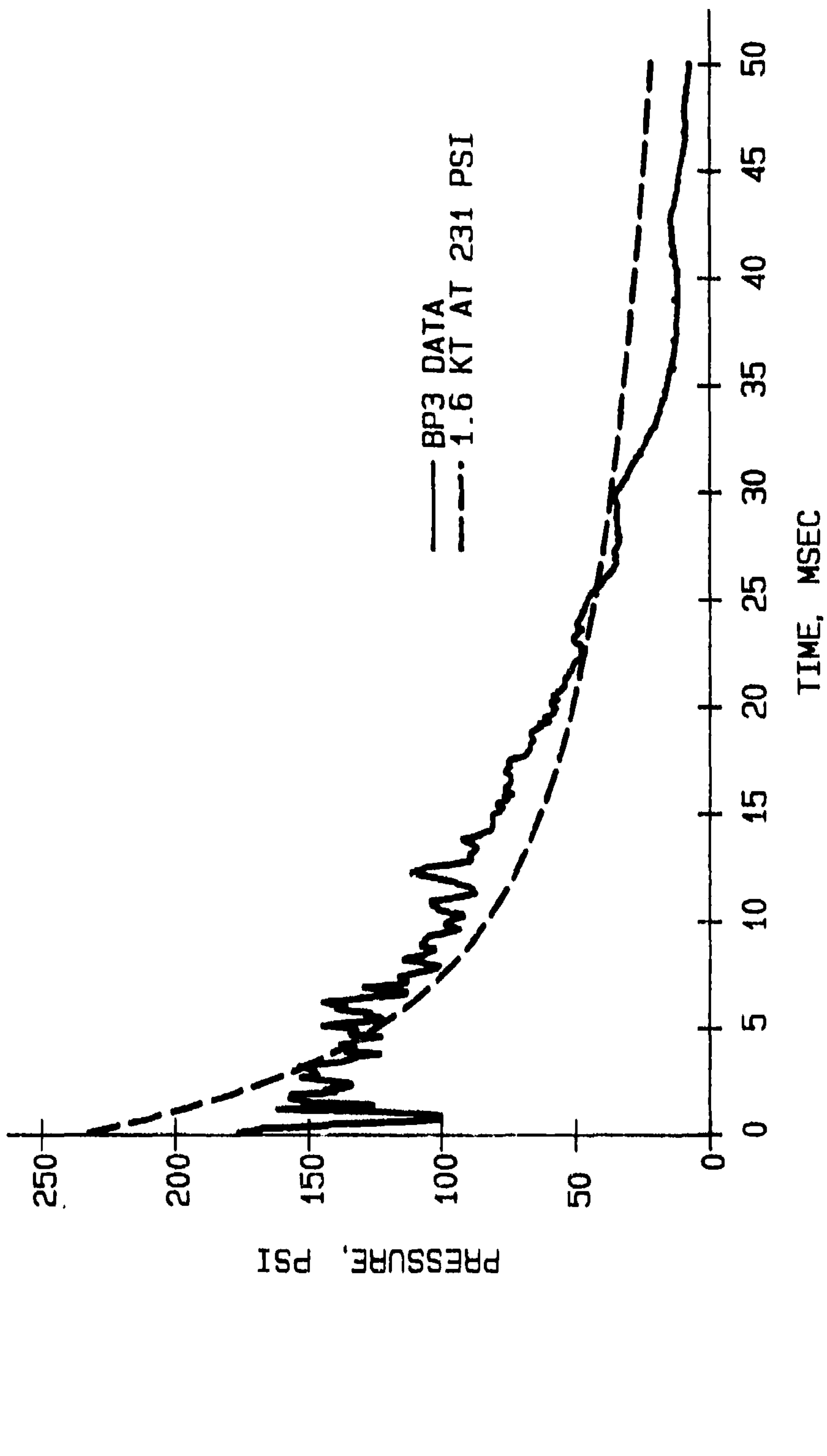


BP2 DATA
3.4 KT AT 171 PSI FIT
IMPULSE, PSI-SEC
0
.5
1
1.5
2
2.5
3
TIME, MSEC
0
5
10
15
20
25
30
35
40
45
50

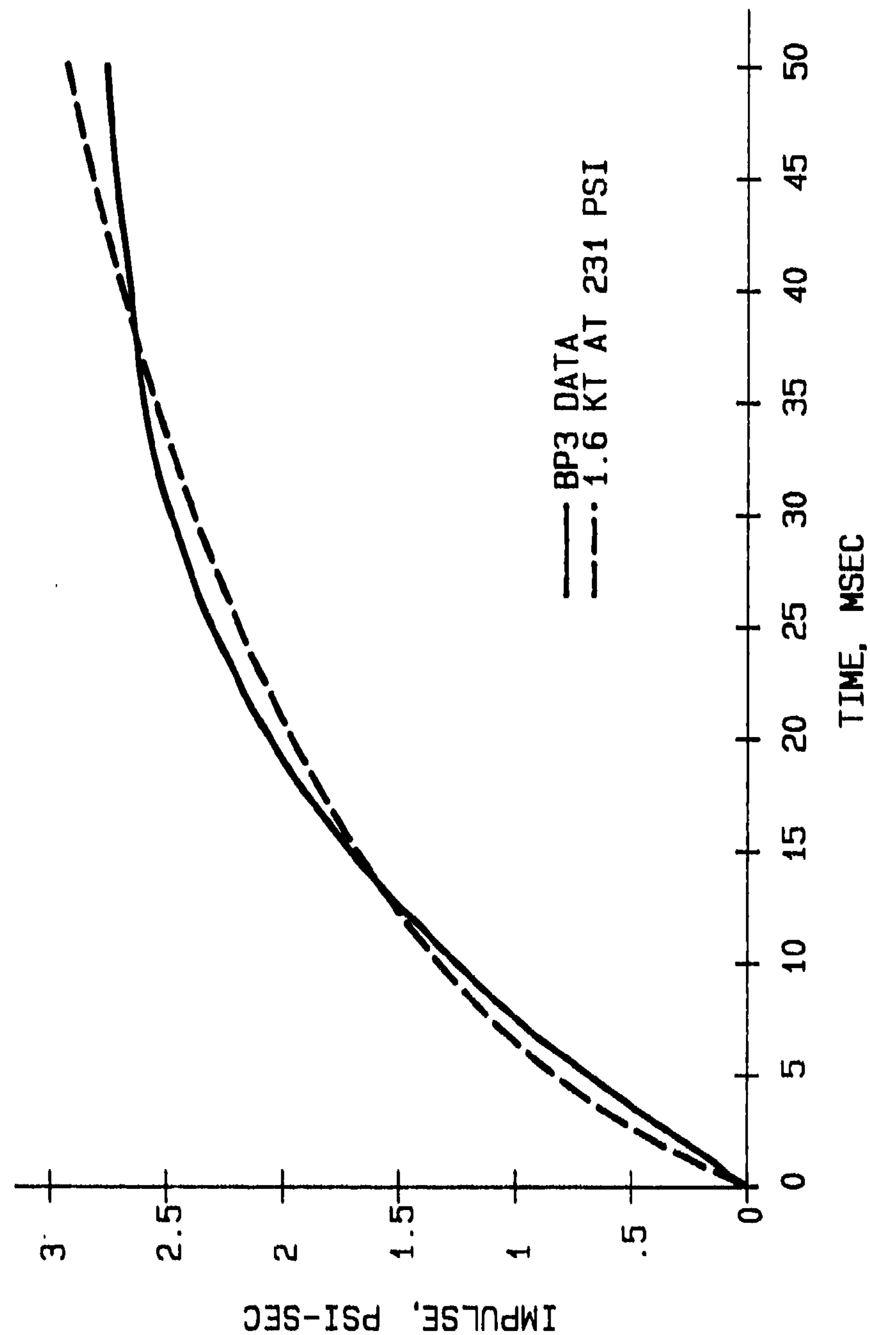


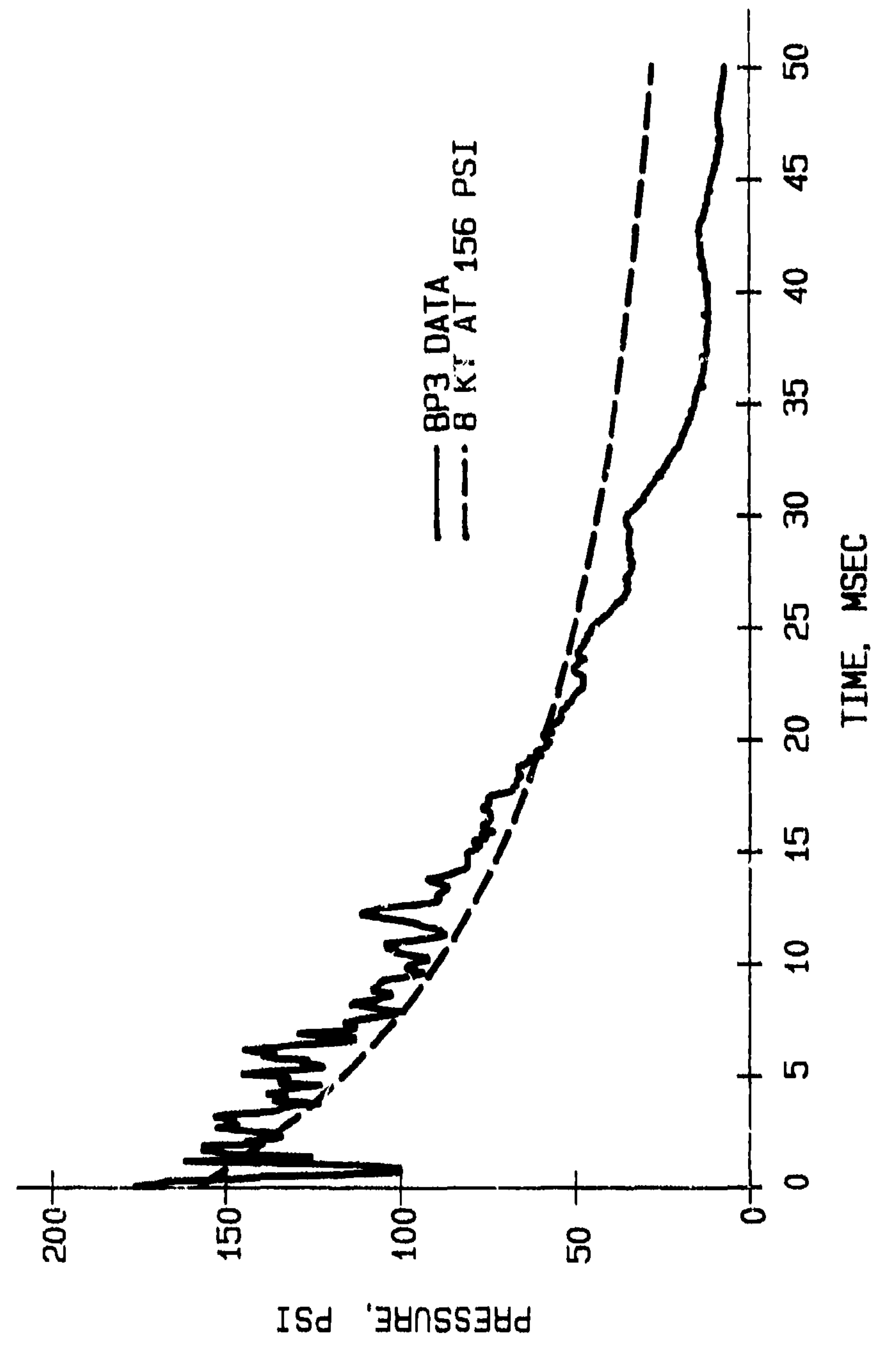
BP2 DATA
8 KT AT 139 PSI
PRESSURE, PSI
TIME, MSEC
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50


BP2 DATA
8 KT AT 139 PSI FIT
TIME, MSEC
IMPULSE, PSI-SEC
0
5
10
15
20
25
30
35
40
45
50
.5
1
1.5
2
2.5
3

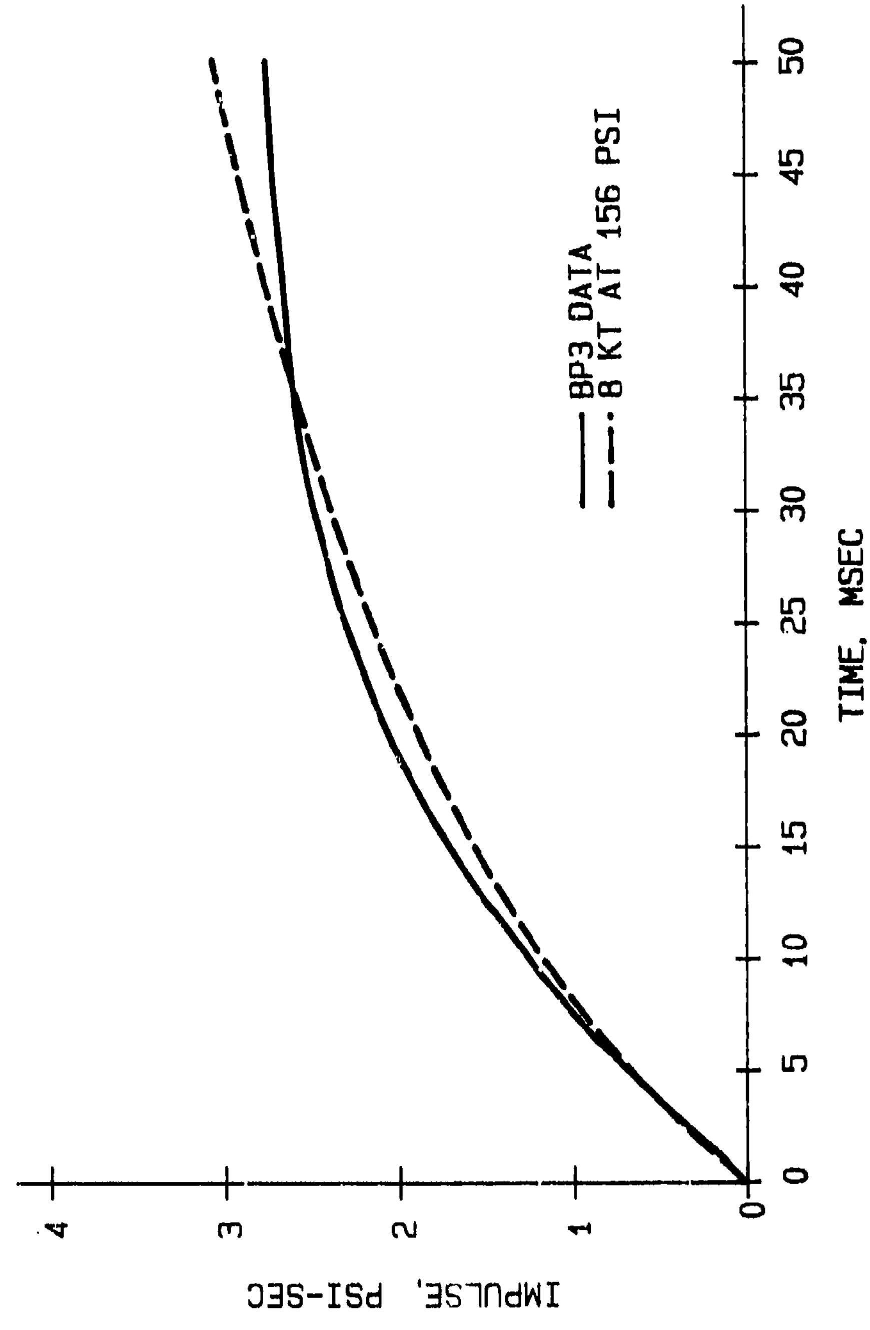


BP3 DATA
1.6 KT AT 231 PSI
PRESSURE, PSI
TIME, MSEC
0
50
100
150
200
250
5
10
15
20
25
30
35
40
45
50

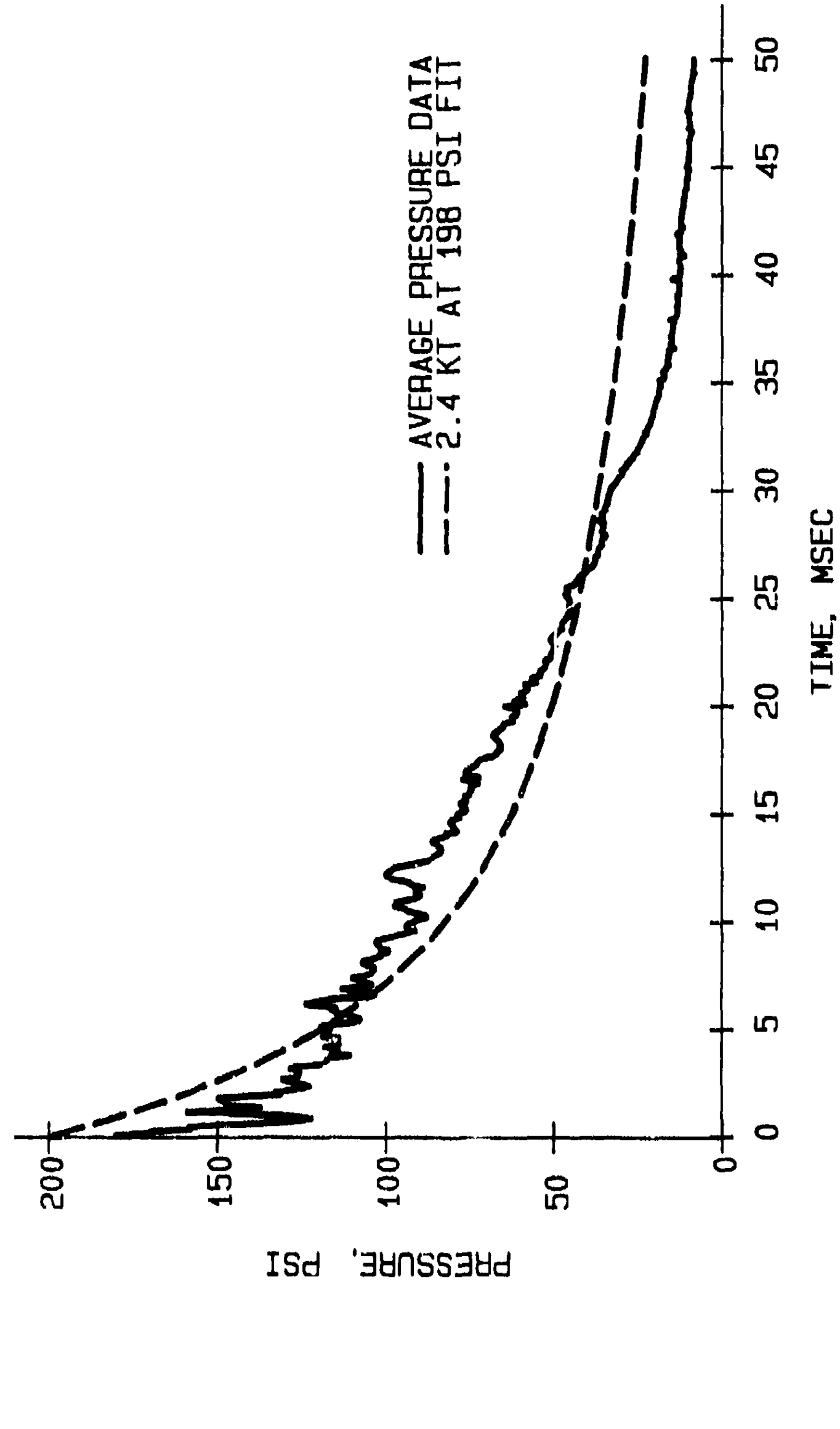

BP3 DATA
1.6 KT AT 231 PSI
IMPULSE, PSI-SEC
0
.5
1
1.5
2
2.5
3
TIME, MSEC
0
5
10
15
20
25
30
35
40
45
50



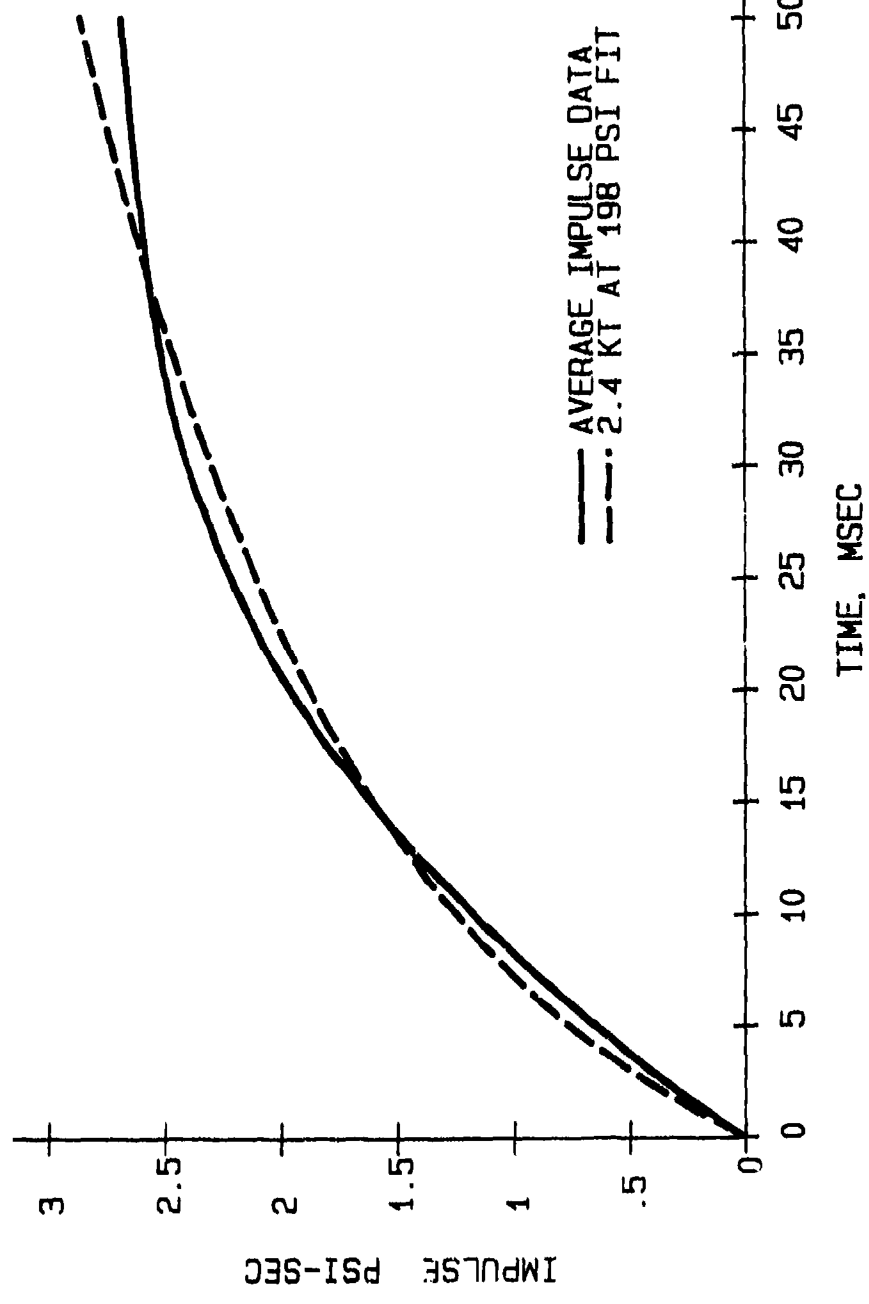
BP3 DATA
8 KT AT 156 PSI
PRESSURE, PSI
0
50
100
150
200
TIME, MSEC
0
5
10
15
20
25
30
35
40
45
50

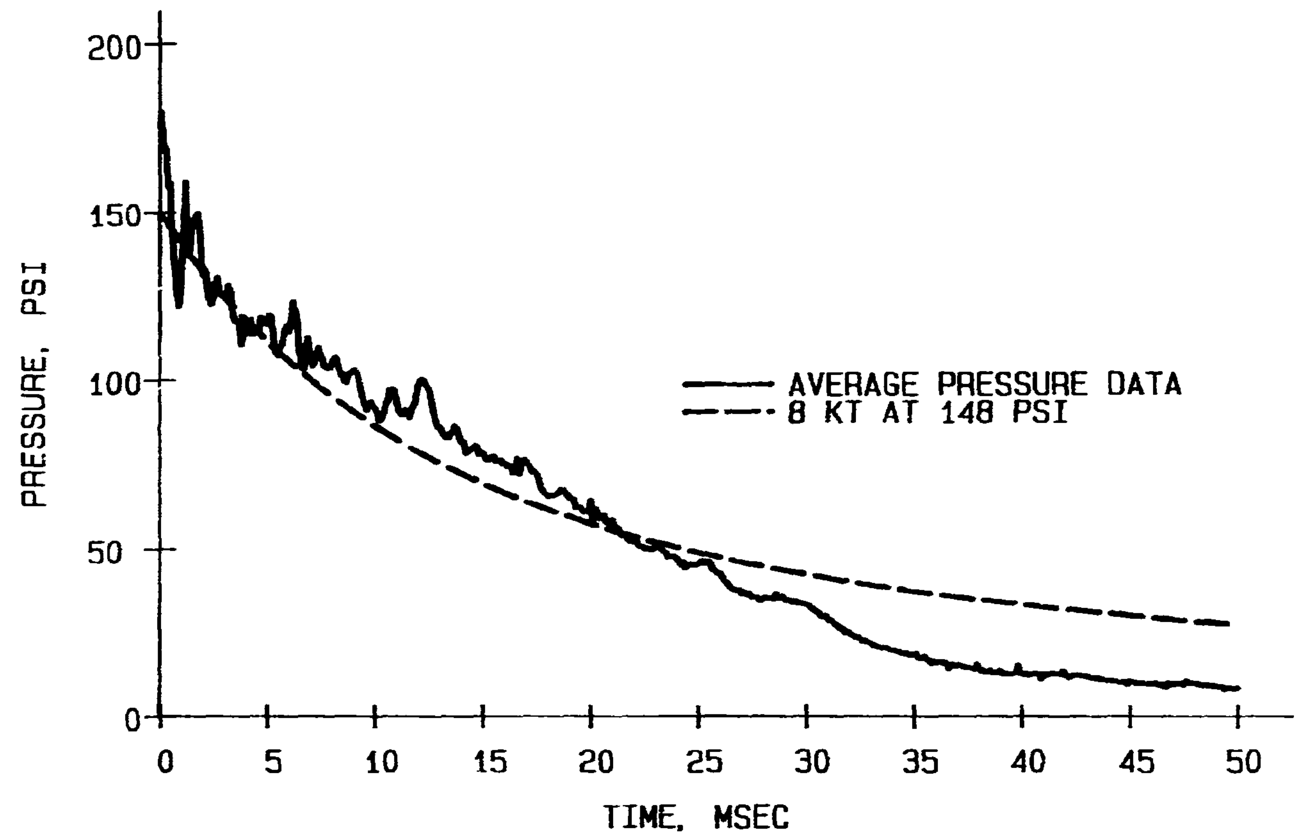


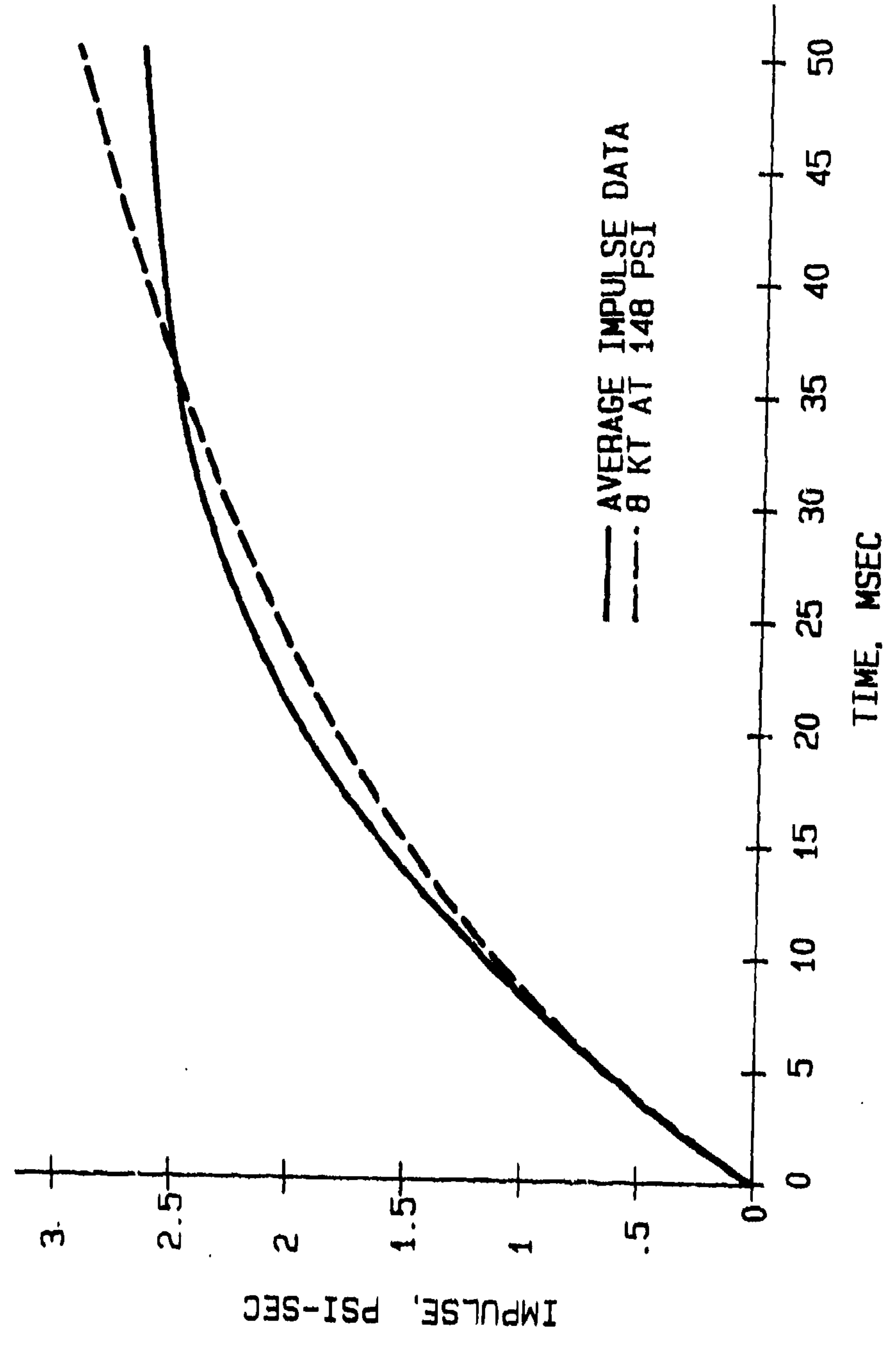
BP3 DATA
8 KT AT 156 PSI
TIME, MSEC
IMPULSE, PSI-SEC
0
5
10
15
20
25
30
35
40
45
50
1
2
3
4



AVERAGE PRESSURE DATA
2.4 KT AT 198 PSI FIT
PRESSURE, PSI
TIME, MSEC
0
50
100
150
200
0
5
10
15
20
25
30
35
40
45
50


AVERAGE IMPULSE DATA
2.4 KT AT 198 PSI FIT
TIME, MSEC
IMPULSE PSI-SEC
0
5
10
15
20
25
30
35
40
45
50
.5
1
1.5
2
2.5
3


AVERAGE PRESSURE DATA
8 KT AT 148 PSI
PRESSURE, PSI
TIME, MSEC
0
50
100
150
200
0
5
10
15
20
25
30
35
40
45
50



IMPULSE, PSI-SEC
0
.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40
45
50
TIME, MSEC
AVERAGE IMPULSE DATA
8 KT AT 148 PSI